# 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency

# Version 7.0

# Volume 3: Residential Measures

## FINAL

## September 28, 2018

## Effective:

## January 1, 2019

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**VOLUME 1: OVERVIEW AND USER GUIDE**

**VOLUME 2: COMMERCIAL AND INDUSTRIAL MEASURES**

## VOLUME 4: CROSS-CUTTING MEASURES AND ATTACHMENTS

# Volume 3: Residential Measures

## 5.1 Appliances End Use

### 5.1.1 ENERGY STAR Air Purifier/Cleaner

**DESCRIPTION**

An air purifier (cleaner) meeting the efficiency specifications of ENERGY STAR is purchased and installed in place of a model meeting the current federal standard.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is defined as an air purifier meeting the efficiency specifications of ENERGY STAR as provided below.

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust[1] to be considered under this specification.
- Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)
- Standby Power Requirement: = 2.0 Watts Qualifying models that perform secondary consumer functions (e.g. clock, remote control) must meet the standby power requirement.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is assumed to be a conventional unit[2].

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 9 years[3].

**DEEMED MEASURE COST**

The incremental cost for this measure is $70.[4]

**LOADSHAPE**

Loadshape C53 - Flat

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is assumed to be 100 % (the unit is assumed to be always on).

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[1] Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard

[2] As defined as the average of non-ENERGY STAR products found in EPA research, 2011, ENERGY STAR Qualified Room Air Cleaner Calculator.

[3] ENERGY STAR Qualified Room Air Cleaner Calculator.

[4] Ibid

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

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

Where:

$kWh_{BASE}$ = Baseline kWh consumption per year[5]

= see table below

$kWh_{ESTAR}$ = ENERGY STAR kWh consumption per year[6]

= see table below

| Clean Air Delivery Rate (CADR) | CADR used in calculation (midpoint) | Baseline Unit Energy Consumption (kWh/year) | ENERGY STAR Unit Energy Consumption (kWh/year) | ΔkWH |
|---|---|---|---|---|
| CADR 51-100 | 75 | 441 | 148 | 293 |
| CADR 101-150 | 125 | 733 | 245 | 488 |
| CADR 151-200 | 175 | 1025 | 342 | 683 |
| CADR 201-250 | 225 | 1317 | 440 | 877 |
| CADR Over 250 | 300 | 1755 | 586 | 1169 |

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5844 hours[7]

CF = Summer Peak Coincidence Factor for measure

= 66.7%[8]

| Clean Air Delivery Rate | ΔkW |
|---|---|
| CADR 51-100 | 0.033 |
| CADR 101-150 | 0.056 |
| CADR 151-200 | 0.078 |
| CADR 201-250 | 0.100 |
| CADR Over 250 | 0.133 |

### NATURAL GAS SAVINGS

N/A

[5] ENERGY STAR Qualified Room Air Cleaner Calculator.
[6] Ibid.
[7] Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator assumption of 16 hours per day (16 * 365.25 = 5844).
[8] Assumes that the purifier usage is evenly spread throughout the year, therefore coincident peak is calculated as 5844/8766 = 66.7%.

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

There are no operation and maintenance cost adjustments for this measure.[9]

### MEASURE CODE: RS-APL-ESAP-V02-160601

### REVIEW DEADLINE: 1/1/2023

[9] Some types of room air cleaners require filter replacement or periodic cleaning, but this is likely to be true for both efficient and baseline units and so no difference in cost is assumed.

## 5.1.2 ENERGY STAR Clothes Washers

### DESCRIPTION

This measure relates to the installation of a clothes washer meeting the ENERGY STAR or CEE Tier 2 minimum qualifications. Note if the DHW and dryer fuels of the installations are unknown (for example through a retail program) savings should be based on a weighted blend using RECS data (the resultant values (kWh, therms and gallons of water) are provided). The algorithms can also be used to calculate site specific savings where DHW and dryer fuels are known.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

Clothes washer must meet the ENERGY STAR or CEE Tier 2 minimum qualifications, as required by the program.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard sized clothes washer meeting the minimum federal baseline as of January 2018[10].

| Efficiency Level | Top Loading >2.5 Cu ft | Front Loading >2.5 Cu ft |
|---|---|---|
| Federal Standard | ≥1.57 IMEF, ≤6.5 IWF | ≥1.84 IMEF, ≤4.7 IWF |
| ENERGY STAR | ≥2.06 IMEF, ≤4.3 IWF | ≥2.76 IMEF, ≤3.2 IWF |
| CEE Tier 2 | ≥2.92 IMEF, ≤3.2 IWF | |

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years[11].

### DEEMED MEASURE COST

The incremental cost for an ENERGY STAR unit is assumed to be $84 and for a CEE Tier 2 unit it is $141[12].

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

Loadshape R01 - Residential Clothes Washer

### COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%[13].

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[10] DOE Energy Conservation Standards for Clothes Washers, Appliance and Equipment Standard, 10 CFR Part 430.32(g)

[11] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool.

[12] Cost estimates are based on Navigant analysis for the Department of Energy (see CW Analysis_05032018.xls). This analysis looked at incremental cost and shipment data from manufacturers and the Association of Home Appliance Manufacturers and attempts to find the costs associated only with the efficiency improvements. The ENERGY STAR level in this analysis was made the baseline (as it is now equivalent), the CEE Tier 2 level was extrapolated based on equal rates. Note these assumptions should be reviewed as qualifying product becomes available.

[13] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

1. Calculate clothes washer savings based on the Integrated Modified Energy Factor (IMEF).

   The Integrated Modified Energy Factor (IMEF) includes unit operation, standby, water heating, and drying energy use: "*IMEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, the energy required for removal of the remaining moisture in the wash load, D, and the combined low-power mode energy consumption*" [14].

   The hot water and dryer savings calculated here assumes electric DHW and Dryer (this will be separated in Step 2).

IMEFsavings[15] = Capacity * (1/IMEFbase - 1/IMEFeff) * Ncycles

Where

Capacity = Clothes Washer capacity (cubic feet)

= Actual. If capacity is unknown assume 3.50 cubic feet [16]

IMEFbase = Integrated Modified Energy Factor of baseline unit

= 1.75[17]

IMEFeff = Integrated Modified Energy Factor of efficient unit

= Actual. If unknown assume average values provided below.

Ncycles = Number of Cycles per year

= 264[18]

IMEFsavings is provided below based on deemed values[19]:

| Efficiency Level | IMEF | IMEF Savings (kWh) |
|---|---|---|
| Federal Standard | 1.75 | 0.0 |
| ENERGY STAR | 2.23 | 113 |
| CEE Tier 2 | 2.92 | 211 |

[14] Definition provided on the ENERGY STAR website.

[15] IMEFsavings represents total kWh only when water heating and drying are 100% electric.

16 Based on the average clothes washer volume of all units that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 05/03/2018. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[17] Weighted average IMEF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR product in the CEC database (products accessed on 05/03/2018).

[18] Weighted average of clothes washer cycles per year (based on 2015 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, West North Central Census Division.
If utilities have specific evaluation results providing a more appropriate assumption for single-family or Multifamily homes, in a particular market, or geographical area then that should be used.

[19] IMEF values are the weighted average of the new ENERGY STAR specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and CEE Tier 2 products in the CEC database. See "CW Analysis_05032018.xls" for the calculation.

2. Break out savings calculated in Step 1 for electric DHW and electric dryer

ΔkWh = [Capacity * 1/IMEFbase * Ncycles * (%CWbase + (%DHWbase * %Electric_DHW) + (%Dryerbase * %Electric_Dryer))] - [Capacity * 1/IMEFeff * Ncycles * (%CWeff + (%DHWeff * %Electric_DHW) + (%Dryereff * %Electric_Dryer))]

Where:

%CW = Percentage of total energy consumption for Clothes Washer operation (different for baseline and efficient unit – see table below)

%DHW = Percentage of total energy consumption used for water heating (different for baseline and efficient unit – see table below)

%Dryer = Percentage of total energy consumption for dryer operation (different for baseline and efficient unit – see table below)

| | Percentage of Total Energy Consumption[20] | | |
|---|---|---|---|
| | %CW | %DHW | %Dryer |
| Baseline | 8.1% | 26.5% | 65.4% |
| ENERGY STAR | 5.8% | 31.2% | 63.0% |
| CEE Tier 2 | 13.9% | 9.6% | 76.5% |

%Electric_DHW = Percentage of DHW savings assumed to be electric

| DHW fuel | %Electric_DHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 32%[21] |

%Electric_Dryer = Percentage of dryer savings assumed to be electric

| Dryer fuel | %Electric_Dryer |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 62%[22] |

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

[20] The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units based on data from DOE Life-Cycle Cost and Payback Period Excel-based analytical tool. See "CW Analysis_05032018.xls" for the calculation.

[21] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2015 for Midwest Region, East North Central Census Division. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[22] Default assumption for unknown is based on percentage of homes with electric dryer from EIA Residential Energy Consumption Survey (RECS) 2015 for Midwest Region, East North Central Census Division. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

| | ΔkWH | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer | Electric DHW Unknown Dryer | Gas DHW Unknown Dryer | Unknown DHW Electric Dryer | Unknown DHW Gas Dryer | Unknown DHW Unknown Dryer |
| ENERGY STAR | 112.8 | 120.5 | 29.1 | 18.8 | 80.8 | 70.5 | 105.8 | 22.1 | 73.8 |
| CEE Tier 2 | 211 | 101.9 | 108.2 | -0.9 | 171.7 | 62.6 | 137.1 | 34.3 | 97.8 |

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.

$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[23]

Using defaults provided:

ENERGY STAR $\Delta kWh_{water}$ = 1159/1,000,000*5,010

= 5.8 kWh

ENERGY STAR Most Efficient $\Delta kWh_{water}$ = 1931/1,000,000*5,010

= 9.7 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above Note do not include the secondary savings in this calculation.

Hours = Assumed Run hours of Clothes Washer

= 264 hours[24]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[25]

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

[23] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[24] Based on a weighted average of 264 clothes washer cycles per year assuming an average load runs for one hour (2015 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, West North Central Census Division)

[25] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

| | ΔkW | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer | Electric DHW Unknown Dryer | Gas DHW Unknown Dryer | Unknown DHW Electric Dryer | Unknown DHW Gas Dryer | Unknown DHW Unknown Dryer |
| ENERGY STAR | 0.0162 | 0.0148 | 0.0042 | 0.0027 | 0.0116 | 0.0101 | 0.0152 | 0.0032 | 0.0106 |
| CEE Tier 3 | 0.0304 | 0.0147 | 0.0156 | -0.0001 | 0.0247 | 0.0090 | 0.0197 | 0.0049 | 0.0141 |

### NATURAL GAS SAVINGS

Break out savings calculated in Step 1 of electric energy savings (MEF savings) and extract Natural Gas DHW and Natural Gas dryer savings from total savings:

ΔTherm = [(Capacity * 1/IMEFbase * Ncycles * ((%DHWbase * %Natural Gas_DHW * R_eff) + (%Dryerbase * %Gas _Dryer))) – (Capacity * 1/IMEFeff * Ncycles * ((%DHWeff * %Natural Gas_DHW * R_eff) + (%Dryereff * %Gas_Dryer)))] * Therm_convert

Where:

Therm_convert = Convertion factor from kWh to Therm

= 0.03412

R_eff = Recovery efficiency factor

= 1.26[26]

%Natural Gas_DHW = Percentage of DHW savings assumed to be Natural Gas

| DHW fuel | %Natural Gas_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 62%[27] |

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

| Dryer fuel | %Gas_Dryer |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 36%[28] |

Other factors as defined above

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

[26] To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (see ENERGY STAR Waste Water Recovery Guidelines). Therefore a factor of 0.98/0.78 (1.26) is applied.

[27] Default assumption for unknown fuel is based on percentage of homes with gas dryer from EIA Residential Energy Consumption Survey (RECS) 2015 for Midwest Region, East North Central Census Division If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[28] Ibid.

| | ΔTherms | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer | Electric DHW Unknown Dryer | Gas DHW Unknown Dryer | Unknown DHW Electric Dryer | Unknown DHW Gas Dryer | Unknown DHW Unknown Dryer |
| ENERGY STAR | 0.0 | 0.4 | 2.9 | 3.3 | 1.0 | 1.5 | 0.3 | 3.1 | 1.3 |
| CEE Tier 3 | 0.0 | 4.7 | 3.5 | 8.2 | 5.9 | 5.9 | 2.9 | 6.4 | 4.2 |

## WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = Capacity * (IWFbase - IWFeff) * Ncycles

Where

ΔWater (gallons) = Water saved, in gallons

IWFbase = Integrated Water Factor of baseline clothes washer

= 5.29[29]

IWFeff = Water Factor of efficient clothes washer

= Actual. If unknown assume average values provided below.

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

| Efficiency Level | IWF[30] | ΔWater (gallons per year) |
|---|---|---|
| Federal Standard | 5.29 | 0.0 |
| ENERGY STAR | 4.04 | 1,159 |
| ENERGY STAR Most Efficient | 3.20 | 1,931 |

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: RS-APL-ESCL-V06-190101

## REVIEW DEADLINE: 1/1/2020

[29] Weighted average IWF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR product in the CEC database (products accessed on 05/03/2018).

[30] IWF values are the weighted average of the new ENERGY STAR specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and CEE Tier 2 products in the CEC database (products accessed on 05/03/2018). See "CW Analysis_05032018.xls" for the calculation.

## 5.1.3 ENERGY STAR Dehumidifier

### Description

A dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR Version 4.0 (effective 10/25/2016) and ENERGY STAR Most Efficient 2018 Criteria (effective 01/01/2018) is purchased and installed in a residential setting in place of a unit that meets the minimum federal standard efficiency.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards as defined below:

| Capacity (pints/day) | ENERGY STAR Criteria (L/kWh) | ENERGY STAR Most Efficient: Stand Alone (L/kWh) | ENERGY STAR Most Efficient: Whole House (L/kWh) |
|---|---|---|---|
| <75 | ≥2.00 | ≥2.20 | ≥2.30 |
| 75 to ≤185 | ≥2.80 | N/A | N/A |

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

### Definition of Baseline Equipment

The baseline for this measure is defined as a new dehumidifier that meets the federal efficiency standards. The Federal Standard for Dehumidifiers as of October 2012 is defined below:

| Capacity (pints/day) | Federal Standard Criteria (L/kWh) |
|---|---|
| Up to 35 | ≥1.35 |
| > 35 to ≤ 45 | ≥1.50 |
| > 45 to ≤ 54 | ≥1.60 |
| > 54 to ≤ 75 | ≥1.70 |
| > 75 to ≤ 185 | ≥2.50 |

Effective June 13, 2019 new federal standards for dehumidifiers become active and are detailed in the table below. This change to baseline will be made effective 1/1/2020 to allow for sell through of product:

| Equipment Specification | Capacity (pints/day) | Federal Standard Criteria (L/kWh) |
|---|---|---|
| Portable dehumidifier | Up to 25 | ≥1.30 |
| | > 25 to ≤ 50 | ≥1.60 |
| | > 50 | ≥2.80 |

| Equipment Specification | Product Case Volume (cubic feet) | Federal Standard Criteria (L/kWh) |
|---|---|---|
| Whole-home dehumidifier | Up to 8 | ≥1.77 |
| | > 8 | ≥2.41 |

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the measure is 12 years[31].

### DEEMED MEASURE COST

The incremental cost for an ENERGY STAR unit is assumed to be $9.52[32] and for an ENERGY STAR Most Efficient unit is $75[33].

### LOADSHAPE

Loadshape R12 - Residential - Dehumidifier

### COINCIDENCE FACTOR

The coincidence factor is assumed to be 37% [34].

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = (((Avg Capacity * 0.473) / 24) * Hours) * (1 / (L/kWh_Base) – 1 / (L/kWh_Eff))

Where:

Avg Capacity = Average capacity of the unit (pints/day)

= Actual, if unknown assume capacity in each capacity range as provided in table below, or if capacity range unknown assume average.

0.473 = Constant to convert Pints to Liters

24 = Constant to convert Liters/day to Liters/hour

Hours = Run hours per year

= 1632 [35]

L/kWh = Liters of water per kWh consumed, as provided in tables above

Annual kWh results for each capacity class are presented below:

[31] EPA Research, 2012; ENERGY STAR Dehumidifier Calculator

[32] Based on incremental costs sourced from the 2016 ENERGY STAR Appliance Calculator and weighted by capacity based on ENERGY STAR qualified products, accessed on July 2016.

[33] DOE Energy Conservation Standards for Residential Dehumidifiers, Appliance and Equipment Standard, 10 CFR Part 430, July 23, 2012, page 73. The sourced table is an analysis on the incremental manufacturer product costs on dehumidifiers with varying incentive levels. Assuming the markup costs between the baseline units and the most efficient units are equal. The incremental cost reproduced is a straight average of all the dehumidifiers, both stand alone and whole house, with an efficiency level meeting or exceeding ENERGY STAR's Most Efficient criteria. Opted to combine the incremental cost into one value because the stand alone and whole house incremental costs were near identical.

[34] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

[35] ENERGY STAR Dehumidifier Calculator; 24 hour operation over 68 days of the year.

| Capacity Range (pints/day) | Capacity Used (pints/day) | Federal Standard Criteria (≥ L/kWh) | ENERGY STAR Criteria (≥ L/kWh) | ENERGY STAR Most Efficient: Stand Alone (≥ L/kWh) | ENERGY STAR Most Efficient: Whole House (≥ L/kWh) | Annual kWh | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Federal Standard | ENERGY STAR | ENERGY STAR Most Efficient: Stand Alone | ENERGY STAR Most Efficient: Whole House |
| ≤25 | 20 | 1.35 | 2.00 | 2.20 | 2.30 | 477 | 322 | 292 | 280 |
| > 25 to ≤35 | 30 | 1.35 | 2.00 | 2.20 | 2.30 | 715 | 482 | 439 | 420 |
| > 35 to ≤45 | 40 | 1.50 | 2.00 | 2.20 | 2.30 | 858 | 643 | 585 | 559 |
| > 45 to ≤ 54 | 50 | 1.60 | 2.00 | 2.20 | 2.30 | 1,005 | 804 | 731 | 699 |
| > 54 to ≤ 75 | 65 | 1.70 | 2.00 | 2.20 | 2.30 | 1,230 | 1,045 | 950 | 909 |
| > 75 to ≤ 185 | 130 | 2.50 | 2.80 | N/A | N/A | 1,673 | 1493 | N/A | N/A |
| Average[36] | 57.6 | 1.60 | 2.00 | 2.20 | 2.30 | 1,155 | 926 | 842 | 805 |

| Capacity Range (pints/day) | Capacity Used (pints/day) | Energy Savings (kWh) | | |
|---|---|---|---|---|
| | | ENERGY STAR | ENERGY STAR Most Efficient: Stand Alone | ENERGY STAR Most Efficient: Whole House |
| ≤25 | 20 | 155 | 184 | 197 |
| > 25 to ≤35 | 30 | 232 | 276 | 295 |
| > 35 to ≤45 | 40 | 214 | 273 | 298 |
| > 45 to ≤ 54 | 50 | 201 | 274 | 306 |
| > 54 to ≤ 75 | 65 | 184 | 280 | 321 |
| > 75 to ≤ 185 | 130 | 179 | N/A | N/A |
| Average | 57.6 | 229 | 313 | 350 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

Hours = Annual operating hours

= 1632 hours [37]

CF = Summer Peak Coincidence Factor for measure

= 0.37 [38]

Summer coincident peak demand results for each capacity class are presented below:

[36] The relative weighting of each product class is based on number of units on the ENERGY STAR certified list, accessed in July 2016. See "Dehumidifier Calcs_05082018.xls.

[37] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator

[38] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

| | Annual Summer Peak kW Savings | | |
|---|---|---|---|
| Capacity (pints/day) Range | ENERGY STAR | ENERGY STAR Most Efficient: Stand Alone | ENERGY STAR Most Efficient: Whole House |
| ≤25 | 0.035 | 0.042 | 0.045 |
| > 25 to ≤35 | 0.053 | 0.063 | 0.067 |
| > 35 to ≤45 | 0.049 | 0.062 | 0.068 |
| > 45 to ≤ 54 | 0.046 | 0.062 | 0.069 |
| > 54 to ≤ 75 | 0.042 | 0.063 | 0.073 |
| > 75 to ≤ 185 | 0.041 | N/A | N/A |
| Average | 0.052 | 0.071 | 0.079 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESDH-V05-190101**

**REVIEW DEADLINE: 1/1/2020**

## 5.1.4 ENERGY STAR Dishwasher

### DESCRIPTION

A standard or compact residential dishwasher meeting ENERGY STAR standards is installed in place of a model meeting the federal standard.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a standard or compact dishwasher meeting the ENERGY STAR standards presented in the table below.

**ENERGY STAR Requirements (Version 3.0, Effective January 29, 2016)**

| Dishwasher Type | Maximum kWh/year | Maximum gallons/cycle |
|---|---|---|
| Standard<br>(≥ 8 place settings + six serving pieces) | 270 | 3.5 |
| Standard with Connected Functionality[39] | 283 | |
| Compact<br>(< 8 place settings + six serving pieces) | 203 | 3.1 |

### DEFINITION OF BASELINE EQUIPMENT

The baseline reflects the minimum federal efficiency standards for dishwashers effective May 30, 2013, as presented in the table below.

| Dishwasher Type | Maximum kWh/year | Maximum gallons/cycle |
|---|---|---|
| Standard | 307 | 5.0 |
| Compact | 222 | 3.5 |

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the measure is 11 years[40].

### DEEMED MEASURE COST

The incremental cost[41] for standard and compact dishwashers is provided in the table below.

| Dishwasher Type | Baseline Cost | ENERGY STAR Cost | Incremental Cost |
|---|---|---|---|
| Standard | $255.63 | $331.30 | $75.67 |

[39] The new ENERGY STAR specification "establishes optional connected criteria for dishwashers. ENERGY STAR certified dishwashers with connected functionality offer favorable attributes for demand response programs to consider, since their peak energy consumption is relatively high, driven by water heating. ENERGY STAR certified dishwashers with connected functionality will offer consumers new convenience and energy-saving features, such as alerts for cycle completion and/or recommended maintenance, as well as feedback on the energy use of the product". See 'ENERGY STAR Residential Dishwasher Final Version 6.0 Cover Memo.pdf'. Calculated as per Version 6.0 specification; "ENERGY STAR Residential Dishwasher Version 6.0 Final Program Requirements.pdf". Note that the potential for demand response and additional peak savings from units with Connected Functionality have not been explored. This could be a potential addition in a future version.

[40] Measure lifetime from California DEER. See file California DEER 2014-EUL Table - 2014 Update.xlsx.

[41] Costs are based on data from U.S. DOE, Final Rule Life-Cycle Cost (LCC) Spreadsheet. See file Residential Dishwasher Analysis_Nov2017.xlsx for cost calculation details.

| Dishwasher Type | Baseline Cost | ENERGY STAR Cost | Incremental Cost |
|---|---|---|---|
| Compact | $290.13 | $308.62 | $18.49 |

**LOADSHAPE**

Loadshape R02 - Residential Dish Washer

**COINCIDENCE FACTOR**

The coincidence factor is assumed to be 2.6%[42].

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh^{43} = ((kWh_{Base} - kWh_{ESTAR}) * (\%kWh\_op + (\%kWh\_heat * \%Electric\_DHW)))$$

Where:

$kWh_{BASE}$ = Baseline kWh consumption per year

| Dishwasher Type | Maximum kWh/year |
|---|---|
| Standard | 307 |
| Compact | 222 |

$kWh_{ESTAR}$ = ENERGY STAR kWh annual consumption

| Dishwasher Type | Maximum kWh/year |
|---|---|
| Standard | 270 |
| Standard with Connected Functionality | 283 |
| Compact | 203 |

%kWh_op = Percentage of dishwasher energy consumption used for unit operation

= 1 - 56%[44]

= 44%

%kWh_heat = Percentage of dishwasher energy consumption used for water heating

= 56%[45]

%Electric_DHW = Percentage of DHW savings assumed to be electric

| DHW fuel | %Electric_DHW |
|---|---|
| Electric | 100% |

---

[42] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

[43] The Federal Standard and ENERGY STAR annual consumption values include electric consumption for both the operation of the machine and for heating the water that is used by the machine.

[44] ENERGY STAR Appliance Calculator.

[45] Ibid.

| DHW fuel | %Electric_DHW |
|---|---|
| Natural Gas | 0% |
| Unknown | 16%[46] |

| Dishwasher Type | ΔkWh | | |
|---|---|---|---|
| | With Electric DHW | With Gas DHW | With Unknown DHW |
| ENERGY STAR Standard | 37.0 | 16.3 | 19.6 |
| ENERGY STAR Standard with Connected Functionality | 24.0 | 10.6 | 12.7 |
| ENERGY STAR Compact | 19.0 | 8.4 | 10.1 |

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.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[47]

Using defaults provided:

Standard $\Delta kWh_{water}$ = 252/1,000,000*5,010

= 1.3 kWh

Compact $\Delta kWh_{water}$ = 67/1,000,000*5,010

= 0.3 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**[48]

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

Where:

ΔkWh = Annual kWh savings from measure as calculated above. Note do not include the secondary savings in this calculation.

Hours = Annual operating hours[49]

= 353 hours

[46] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[47] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[48] Note that the potential for demand response and additional peak savings from units with Connected Functionality have not been explored. This could be a potential addition in a future version.

[49] Assuming 2.1 hours per cycle and 168 cycles per year therefore 353 operating hours per year. 168 cycles per year is based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data.

CF = Summer Peak Coincidence Factor

= 2.6% [50]

| Dishwasher Type | ΔkW | | |
|---|---|---|---|
| | With Electric DHW | With Gas DHW | With Unknown DHW |
| ENERGY STAR Standard | 0.0027 | 0.0012 | 0.0014 |
| ENERGY STAR Standard with Connected Functionality | 0.0018 | 0.0008 | 0.0009 |
| ENERGY STAR Compact | 0.0014 | 0.0006 | 0.0007 |

### NATURAL GAS SAVINGS

$$\Delta \text{Therm} = (kWh_{Base} - kWh_{ESTAR}) * \%kWh\_heat * \%Natural\ Gas\_DHW * R\_eff * 0.03412$$

Where

%kWh_heat = % of dishwasher energy used for water heating

= 56%

%Natural Gas_DHW = Percentage of DHW savings assumed to be Natural Gas

| DHW fuel | %Natural Gas_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[51] |

R_eff = Recovery efficiency factor

= 1.26[52]

0.03412 = factor to convert from kWh to Therm

| Dishwasher Type | ΔTherms | | |
|---|---|---|---|
| | With Electric DHW | With Gas DHW | With Unknown DHW |
| ENERGY STAR Standard | 0.00 | 0.89 | 0.75 |
| ENERGY STAR Standard with Connected Functionality | 0.00 | 0.58 | 0.49 |
| ENERGY STAR Compact | 0.00 | 0.46 | 0.38 |

### WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water\ (gallons) = Water_{Base} - Water_{EFF}$$

Where

$Water_{Base}$ = water consumption of conventional unit

| Dishwasher Type | $Water_{Base}$ (gallons) [53] |
|---|---|
| Standard | 840 |

[50] End use data from Ameren representing the average DW load during peak hours/peak load.

[51] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[52] To account for the different efficiency of electric and natural gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (see ENERGY STAR Waste Water Heat Recovery Guidelines). Therefore a factor of 0.98/0.78 (1.26) is applied.

[53] Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in

| Dishwasher Type | $Water_{Base}$ (gallons) [53] |
|---|---|
| Compact | 588 |

$Water_{EFF}$ = annual water consumption of efficient unit:

| Dishwasher Type | $Water_{EFF}$ (gallons) [54] |
|---|---|
| Standard | 588 |
| Compact | 521 |

| Dishwasher Type | ΔWater (gallons) |
|---|---|
| ENERGY STAR Standard | 252 |
| ENERGY STAR Compact | 67 |

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESDI-V04-190101**

**REVIEW DEADLINE: 1/1/2022**

Illinois derived from the 2009 RECs data.

[54] Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data.

## 5.1.5 ENERGY STAR Freezer

### DESCRIPTION

A freezer meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard (NAECA). Energy usage specifications are defined in the table below (note, AV is the freezer Adjusted Volume and is calculated as 1.73*Total Volume):

| Product Category | Volume (cubic feet) | Assumptions after September 2014 | |
|---|---|---|---|
| | | Federal Baseline Maximum Energy Usage in kWh/year[55] | ENERGY STAR Maximum Energy Usage in kWh/year[56] |
| Upright Freezers with Manual Defrost | 7.75 or greater | 5.57*AV + 193.7 | 5.01*AV + 174.3 |
| Upright Freezers with Automatic Defrost | 7.75 or greater | 8.62*AV + 228.3 | 7.76*AV + 205.5 |
| Chest Freezers and all other Freezers except Compact Freezers | 7.75 or greater | 7.29*AV + 107.8 | 6.56*AV + 97.0 |
| Compact Upright Freezers with Manual Defrost | < 7.75 and 36 inches or less in height | 8.65*AV + 225.7 | 7.79*AV + 203.1 |
| Compact Upright Freezers with Automatic Defrost | < 7.75 and 36 inches or less in height | 10.17*AV + 351.9 | 9.15*AV + 316.7 |
| Compact Chest Freezers | <7.75 and 36 inches or less in height | 9.25*AV + 136.8 | 8.33*AV + 123.1 |

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a freezer meeting the efficiency specifications of ENERGY STAR, as defined below and calculated above:

| Equipment | Volume | Criteria |
|---|---|---|
| Full Size Freezer | 7.75 cubic feet or greater | At least 10% more energy efficient than the minimum federal government standard (NAECA). |
| Compact Freezer | Less than 7.75 cubic feet and 36 inches or less in height | At least 20% more energy efficient than the minimum federal government standard (NAECA). |

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a model that meets the federal minimum standard for energy efficiency. The standard varies depending on the size and configuration of the freezer (chest freezer or upright freezer, automatic or manual defrost) and is defined in the table above.

[55] See Department of Energy Federal Standards.
[56] See Version 5.0 ENERGY STAR specification.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 22 years[57].

### DEEMED MEASURE COST

The incremental cost for this measure is $35[58].

### LOADSHAPE

Loadshape R04 - Residential Freezer

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 95%[59].

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS:

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

Where:

$kWh_{BASE}$ = Baseline kWh consumption per year as calculated in algorithm provided in table above.

$kWh_{ESTAR}$ = ENERGY STAR kWh consumption per year as calculated in algorithm provided in table above.

For example for a 7.75 cubic foot Upright Freezers with Manual Defrost purchased after September 2014:

$\Delta kWh = (5.57*(7.75* 1.73)+193.7) – (5.01*(7.75* 1.73)+174.3)$

$= 268.4 – 241.5$

$= 26.9$ kWh

If volume is unknown, use the following default values:

| Product Category | Volume Used[60] | Assumptions after September 2014 | | |
|---|---|---|---|---|
| | | $kWh_{BASE}$ | $kWh_{ESTAR}$ | kWh Savings |
| Upright Freezers with Manual Defrost | 27.9 | 349.2 | 314.2 | 35.0 |
| Upright Freezers with Automatic Defrost | 27.9 | 469.0 | 422.2 | 46.8 |
| Chest Freezers and all other Freezers except Compact Freezers | 27.9 | 311.4 | 280.2 | 31.2 |
| Compact Upright Freezers with Manual Defrost | 10.4 | 467.2 | 420.6 | 46.6 |

57 Based on 2011 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
58 Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009.
59 Based on eShapes Residential Freezer load data as provided by Ameren.
60 Volume is based on ENERGY STAR Calculator assumption of 16.14 $ft^3$ average volume, converted to Adjusted volume by multiplying by 1.73.

| Product Category | Volume Used[60] | Assumptions after September 2014 | | |
|---|---|---|---|---|
| | | $kWh_{BASE}$ | $kWh_{ESTAR}$ | kWh Savings |
| Compact Upright Freezers with Automatic Defrost | 10.4 | 635.9 | 572.2 | 63.7 |
| Compact Chest Freezers | 10.4 | 395.1 | 355.7 | 39.4 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/ Hours * CF

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Full Load hours per year

= 5890[61]

CF = Summer Peak Coincident Factor

= 0.95 [62]

For example for a 7.75 cubic foot Upright Freezers with Manual Defrost:

ΔkW = 26.9/5890 * 0.95

= 0.0043 kW

If volume is unknown, use the following default values:

| Product Category | Assumptions after September 2014 |
|---|---|
| | kW Savings |
| Upright Freezers with Manual Defrost | 0.0057 |
| Upright Freezers with Automatic Defrost | 0.0076 |
| Chest Freezers and all other Freezers except Compact Freezers | 0.0050 |
| Compact Upright Freezers with Manual Defrost | 0.0075 |
| Compact Upright Freezers with Automatic Defrost | 0.0103 |
| Compact Chest Freezers | 0.0064 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

[61] Calculated from eShapes Residential Freezer load data as provided by Ameren by dividing total annual load by the maximum kW in any one hour.
[62] Based on eShapes Residential Freezer load data as provided by Ameren.

**MEASURE CODE: RS-APL-ESFR-V03-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.1.6 ENERGY STAR and CEE Tier 2 Refrigerator

### DESCRIPTION

This measure relates to:

a) Time of Sale: the purchase and installation of a new refrigerator meeting either ENERGY STAR or CEE TIER 2 specifications.

b) Early Replacement: the early removal of an existing residential inefficient Refrigerator from service, prior to its natural end of life, and replacement with a new ENERGY STAR or CEE Tier 2 qualifying unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

Energy usage specifications are defined in the table below (note, Adjusted Volume is calculated as the fresh volume + (1.63 * Freezer Volume):

| Product Category | Existing Unit | Assumptions after September 2014 | |
|---|---|---|---|
| | Based on Refrigerator Recycling algorithm | Federal Baseline Maximum Energy Usage in kWh/year[63] | ENERGY STAR Maximum Energy Usage in kWh/year[64] |
| 1. Refrigerators and Refrigerator-freezers with manual defrost | Use Algorithm in 5.1.8 Refrigerator and Freezer Recycling measure to estimate existing unit consumption | 6.79AV + 193.6 | 6.11 * AV + 174.2 |
| 2. Refrigerator-Freezer--partial automatic defrost | | 7.99AV + 225.0 | 7.19 * AV + 202.5 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | | 8.07AV + 233.7 | 7.26 * AV + 210.3 |
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | | 8.51AV + 297.8 | 7.66 * AV + 268.0 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | | 8.85AV + 317.0 | 7.97 * AV + 285.3 |
| 5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | | 9.25AV + 475.4 | 8.33 * AV + 436.3 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | | 8.40AV + 385.4 | 7.56 * AV + 355.3 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service | | 8.54AV + 432.8 | 7.69 * AV + 397.9 |

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

---

[63] See Department of Energy Federal Standards.

[64] See Version 5.0 ENERGY STAR specification.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a refrigerator meeting the efficiency specifications of ENERGY STAR or CEE Tier 2 (defined as requiring >= 10% or >= 15% less energy consumption than an equivalent unit meeting federal standard requirements respectively). The ENERGY STAR standard varies according to the size and configuration of the unit, as shown in table above.

### DEFINITION OF BASELINE EQUIPMENT

Time of Sale: baseline is a new refrigerator meeting the minimum federal efficiency standard for refrigerator efficiency. The current federal minimum standard varies according to the size and configuration of the unit, as shown in table above. Note also that this federal standard will be increased for units manufactured after September 1, 2014.

Early Replacement: the baseline is the existing refrigerator for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

Remaining life of existing equipment is assumed to be 6 years[66]

### DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $40[67] for an ENERGY STAR unit and $140[68] for a CEE Tier 2 unit.

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable assume $451 for ENERGY STAR unit and $551 for CEE Tier 2 unit[69].

The avoided replacement cost (after 4 years) of a baseline replacement refrigerator is $413[70]. This cost should be discounted to present value using the nominal societal discount rate.

### LOADSHAPE

Loadshape R05 - Residential Refrigerator

### COINCIDENCE FACTOR

A coincidence factor is not used to calculate peak demand savings for this measure, see below.

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65 Based on 2011 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
66 Standard assumption of one third of effective useful life.
67 From ENERGY STAR calculator linked above.
68 Based on weighted average of units participating in Efficiency Vermont program and retail cost data provided in Department of Energy, "TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers", October 2005.
69 ENERGY STAR full cost is based upon IL PHA Efficient Living Program data on sample size of 910 replaced units finding average cost of $430 plus an average recycling/removal cost of $21. The CEE Tier 2 estimate uses the delta from the Time of Sale estimate.
70 Calculated using incremental cost from Time of Sale measure and applying inflation rate of 1.91%.

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS:

Time of Sale: $\Delta kWh = UEC_{BASE} - UEC_{EE}$

Early Replacement:

ΔkWh for remaining life of existing unit (1st 4 years) $= UEC_{EXIST} - UEC_{EE}$

ΔkWh for remaining measure life (next 8 years) $= UEC_{BASE} - UEC_{EE}$

Where:

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

$UEC_{BASE}$ = Annual Unit Energy Consumption of baseline unit as calculated in algorithm provided in table above.

$UEC_{EE}$ = Annual Unit Energy Consumption of ENERGY STAR unit as calculated in algorithm provided in table above.

For CEE Tier 2, unit consumption is calculated as 25% lower than baseline.

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8[71]:

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

| Product Category | Existing Unit $UEC_{EXIST}$ [72] | New Baseline $UEC_{BASE}$ | New Efficient $UEC_{EE}$ | | Early Replacement (1st 4 years) ΔkWh | | Time of Sale and Early Replacement (last 8 years) ΔkWh | |
|---|---|---|---|---|---|---|---|---|
| | | | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 |
| 1. Refrigerators and Refrigerator-freezers with manual defrost | 1027.7 | 368.6 | 331.6 | 276.4 | 696.1 | 751.3 | 36.9 | 92.1 |
| 2. Refrigerator-Freezer--partial automatic defrost | 1027.7 | 430.9 | 387.8 | 323.2 | 640.0 | 704.6 | 43.1 | 107.7 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | 814.5 | 441.7 | 397.4 | 331.2 | 417.2 | 483.3 | 44.3 | 110.4 |
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | 1241.0 | 517.1 | 465.4 | 387.8 | 775.6 | 853.1 | 51.7 | 129.3 |

[71] Volume is based on the ENERGY STAR calculator average assumption of 14.75 $ft^3$ fresh volume and 6.76 $ft^3$ freezer volume.
[72] Estimates of existing unit consumption are based on using the 5.1.8 Refrigerator and Freezer Recycling algorithm and the inputs described here: Age = 10 years, Pre-1990 = 0, Size = 21.5 ft3 (from ENERGY STAR calc and consistent with AV of 25.8), Single Door = 0, Side by side = 1 for classifications stating side by side, 0 for classifications stating top/bottom, and 0.5 for classifications that do not distinguish, Primary appliances = 1, unconditioned = 0, Part use factor = 0.

| Product Category | Existing Unit $UEC_{EXIST}$ [72] | New Baseline $UEC_{BASE}$ | New Efficient $UEC_{EE}$ | | Early Replacement (1st 4 years) ΔkWh | | Time of Sale and Early Replacement (last 8 years) ΔkWh | |
|---|---|---|---|---|---|---|---|---|
| | | | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | 814.5 | 545.1 | 490.7 | 408.8 | 323.9 | 405.8 | 54.4 | 136.3 |
| 5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | 814.5 | 713.8 | 651.0 | 535.3 | 163.6 | 279.2 | 62.8 | 178.4 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | 814.5 | 601.9 | 550.1 | 451.4 | 264.4 | 363.2 | 51.7 | 150.5 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service | 1241.0 | 652.9 | 596.1 | 489.6 | 644.9 | 751.3 | 56.8 | 163.2 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = (\Delta kWh/8766) * TAF * LSAF$$

Where:

TAF = Temperature Adjustment Factor

= 1.25[73]

LSAF = Load Shape Adjustment Factor

= 1.057 [74]

If volume is unknown, use the following defaults:

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

[74] Daily load shape adjustment factor (average load in peak period /average daily load) also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 48, using the average Existing Units Summer Profile for hours 13 through 17)

| Product Category | Assumptions after September 2014 standard change ΔkW | | | |
|---|---|---|---|---|
| | Early Replacement (1st 4 years) | | Time of Sale and Early Replacement (last 8 years) | |
| | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 |
| 1. Refrigerators and Refrigerator-freezers with manual defrost | 0.105 | 0.113 | 0.006 | 0.014 |
| 2. Refrigerator-Freezer--partial automatic defrost | 0.096 | 0.106 | 0.006 | 0.016 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | 0.063 | 0.073 | 0.007 | 0.017 |
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | 0.117 | 0.129 | 0.008 | 0.019 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | 0.049 | 0.061 | 0.008 | 0.021 |
| 5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | 0.025 | 0.042 | 0.009 | 0.027 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | 0.040 | 0.055 | 0.008 | 0.023 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service | 0.097 | 0.113 | 0.009 | 0.025 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESRE-V06-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.1.7 ENERGY STAR Room Air Conditioner

### DESCRIPTION

This measure relates to:

a) Time of Sale the purchase and installation of a room air conditioning unit that meets ENERGY STAR version 4.0 which is effective October 26th 2015), in place of a baseline unit. The baseline is based on the Federal Standard effective June 1st, 2014.

| Product Type and Class (Btu/hr) | | Federal Standard with louvered sides (CEER) [75] | Federal Standard without louvered sides (CEER) | ENERGY STAR v4.0 with louvered sides (CEER) [76] | ENERGY STAR v4.0 without louvered sides (CEER) |
|---|---|---|---|---|---|
| Without Reverse Cycle | < 8,000 | 11.0 | 10.0 | 12.1 | 11.0 |
| | 8,000 to 10,999 | 10.9 | 9.6 | 12.0 | 10.6 |
| | 11,000 to 13,999 | 10.9 | 9.5 | 12.0 | 10.5 |
| | 14,000 to 19,999 | 10.7 | 9.3 | 11.8 | 10.2 |
| | 20,000 to 27,999 | 9.4 | 9.4 | 10.3 | 10.3 |
| | >=28,000 | 9.0 | 9.4 | 9.9 | 10.3 |
| With Reverse Cycle | <14,000 | 9.8 | 9.3 | 10.8 | 10.2 |
| | 14,000 to 19,999 | 9.8 | 8.7 | 10.8 | 9.6 |
| | >=20,000 | 9.3 | 8.7 | 10.2 | 9.6 |
| Casement only | | 9.5 | | 10.5 | |
| Casement-Slider | | 10.4 | | 11.4 | |

Side louvers extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models.

Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.

Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.

Reverse cycle refers to the heating function found in certain room air conditioner models.

b) Early Replacement: the early removal of an existing residential inefficient Room AC unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR qualifying unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR version 4.0 (effective October 26th 2015)[77] efficiency standards presented above.

[75] See DOE's Appliance and Equipment Standards for Room AC;
[76] ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
[77] ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements

### DEFINITION OF BASELINE EQUIPMENT

Time of Sale: the baseline assumption is a new room air conditioning unit that meets the Federal Standard (effective June 1st, 2014)[78] efficiency standards as presented above.

Early Replacement: the baseline is the existing Room AC for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years[79].

Remaining life of existing equipment is assumed to be 4 years[80]

### DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $40 for a ENERGY STAR unit[81].

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable assume $448 for ENERGY STAR unit[82].

The avoided replacement cost (after 4 years) of a baseline replacement unit is $432.[83] This cost should be discounted to present value using the nominal societal discount rate.

### LOADSHAPE

Loadshape R08 - Residential Cooling

### COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.3[84].

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Time of Sale: ΔkWh = $(FLH_{RoomAC} * Btu/H * (1/CEERbase - 1/CEERee))/1000$

Early Replacment:

ΔkWh for remaining life of existing unit (1st 4 years) = $(FLH_{RoomAC} * Btu/H * (1/(EERexist/1.01) - 1/CEERee))/1000$

ΔkWh for remaining measure life (next 8 years) = $(FLH_{RoomAC} * Btu/H * (1/CEERbase - 1/CEERee))/1000$

Where:

$FLH_{RoomAC}$ = Full Load Hours of room air conditioning unit

---

78 See DOE's Appliance and Equipment Standards for Room AC.
79 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
80 Standard assumption of one third of effective useful life.
81 Incremental cost based on field study conducted by Efficiency Vermont.
82 Based on IL PHA Efficient Living Program Data for 810 replaced units showing $416 per unit plus $32 average recycling/removal cost.
83 Estimate based upon Time of Sale incremental costs and applying inflation rate of 1.91%.
84 Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

= dependent on location[85]:

| Climate Zone (City based upon) | $FLH_{RoomAC}$ |
|---|---|
| 1 (Rockford) | 220 |
| 2 (Chicago) | 210 |
| 3 (Springfield) | 319 |
| 4 (Belleville) | 428 |
| 5 (Marion) | 374 |
| Weighted Average[86] | 248 |

Btu/H = Size of rebated unit

= Actual. If unknown assume 8500 Btu/hr[87]

EERexist =Efficiency of existing unit

= Actual. If unknown assume 7.7[88]

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption)[89].

CEERbase = Combined Energy Efficiency Ratio of baseline unit

= As provided in tables above

CEERee = Combined Energy Efficiency Ratio of ENERGY STAR unit

= Actual. If unknown assume minimum qualifying standard as provided in tables above

Time of Sale:

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

$\Delta kWH_{ENERGY\ STAR}$ = (248 * 8500 * (1/10.9 – 1/12.0)) / 1000

= 17.7 kWh

Early Replacement:

A 7.7EER, 9000Btu/h unit is removed from a home in Springfield and replaced with an ENERGY STAR unit with louvered sides:

ΔkWh for remaining life of existing unit (1$^{st}$ 4 years) = (319 * 9000 * (1/(7.7/1.01) - 1/12.0))/1000

= 137.3 kWh

ΔkWh for remaining measure life (next 8 years) = (319 * 9000 * (1/10.9 - 1/12.0))/1000

= 24.1 kWh

85 Full load hours for room AC is significantly lower than for central AC. The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling for the same location is 31%. This ratio is applied to those IL cities that have FLH for Central Cooling provided in the ENERGY STAR calculator. For other cities this is extrapolated using the FLH assumptions VEIC have developed for Central AC. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

87 Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

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

89 Since the existing unit will be rated in EER, this factor is used to appropriately compare with the new CEER rating. Version 3.0 of the ENERGY STAR specification provided equivalent EER and CEER ratings and for the most popular size band the EER rating is approximately 1% higher than the CEER. See 'ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements'.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale: ΔkW = Btu/H * ((1/(CEERbase *1.01) - 1/(CEERee * 1.01)))/1000) * CF

Early Replacement: ΔkW = Btu/H * ((1/EERexist - 1/(CEERee * 1.01)))/1000) * CF

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[90]

1.01 = Factor to convert CEER to EER (CEER includes standby and off power consumption)[91].

Other variable as defined above

> Time of Sale:
>
> For example for an 8,500 Btu/H capacity unit, with louvered sides, for an unknown location:
>
> $\Delta kW_{CEE\ TIER\ 1}$ = (8500 * (1/(10.9 * 1.01) – 1/(12.0*1.01))) / 1000 * 0.3
>
> = 0.021 kW
>
> Early Replacement:
>
> A 7.7 EER, 9000Btu/h unit is removed from a home in Springfield and replaced with an ENERGY STAR unit with louvered sides:
>
> ΔkW for remaining life of existing unit (1st 4 years) = (9000 * (1/7.7 - 1/(12.0 * 1.01)))/1000 * 0.3
>
> = 0.128 kW
>
> ΔkW for remaining measure life (next 8 years) = (9000 * (1/(10.9 * 1.01) - 1/(12.0 * 1.01)))/1000 * 0.3
>
> = 0.022 kW

### NATURAL GAS SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: RS-APL-ESRA-V07-190101

### REVIEW DEADLINE: 1/1/2022

[90] Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

[91] Since the new CEER rating includes standby and off power consumption, for peak calculations it is more appropriate to apply the EER rating, but it appears as though new units will only be rated with a CEER rating. Version 3.0 of the ENERGY STAR specification provided equivalent EER and CEER ratings and for the most popular size band the EER rating is approximately 1% higher than the CEER. See ‘ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements’.

## 5.1.8 Refrigerator and Freezer Recycling

### Description

This measure describes savings from the retirement and recycling of inefficient but operational refrigerators and freezers. Savings are provided based on a 2013 workpaper provided by Cadmus that used data from a 2012 ComEd metering study and metering data from a Michigan study, to develop a regression equation that uses key inputs describing the retired unit. The savings are equivalent to the Unit Energy Consumption of the retired unit and should be claimed for the assumed remaining useful life of that unit. A part use factor is applied to account for those secondary units that are not in use throughout the entire year. The reader should note that the regression algorithm is designed to provide an accurate portrayal of savings for the population as a whole and includes those parameters that have a significant effect on the consumption. The precision of savings for individual units will vary.

For Net to Gross factor considerations, please refer to section 4.2 Appliance Recycling Protocol of Appendix A: Illinois Statewide Net-to-Gross Methodologies of Volume 4.0 Cross Cutting Measures and Attachments.

This measure was developed to be applicable to the following program types: ERET.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

N/A

### Definition of Baseline Equipment

The existing inefficient unit must be operational and have a capacity of between 10 and 30 cubic feet.

### Deemed Lifetime of Efficient Equipment

The estimated remaining useful life of the recycling units is 6.5 years [92].

### Deemed Measure Cost

Measure cost includes the customer's value placed on their lost amenity, any customer transaction costs, and the cost of pickup and recycling of the refrigerator/freezer and should be based on actual costs of running the program. The payment (bounty) a Program Administrator makes to the customer serves as a proxy for the value the customer places on their lost amenity and any customer transaction costs. If unknown assume $170[93] per unit.

### Loadshape

Loadshape R05 - Residential Refrigerator

### Coincidence Factor

The coincidence factor is assumed to be 0.00012.

---

[92] DOE refrigerator and freezer survival curves are used to calculate RUL for each equipment age and develop a RUL schedule. The RUL of each unit in the ARCA database is calculated and the average RUL of the dataset serves as the final measure RUL. Refrigerator recycling data from ComEd (PY7-PY9) and Ameren (PY6-PY8) were used to determined EUL with the DOE survival curves from the 2009 TSD. A weighted average of the retailer ComEd data and the Ameren data results in an average of 6.5 years. See Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[93] The $170 default assumption is based on $120 cost of pickup and recycling per unit and $50 proxy for customer transaction costs and value customer places on their lost amenity. $120 is cost of pickup and recycling based on similar Efficiency Vermont program. $50 is bounty, based on Ameren and ComEd program offerings as of 7/27/15.

**Algorithm**

## CALCULATION OF SAVINGS

### ENERGY SAVINGS[94]

Refrigerators:

Energy savings for refrigerators are based upon a linear regression model using the following coefficients[95]:

| Independent Variable Description | Estimate Coefficient |
|---|---|
| Intercept | 83.324 |
| Age (years) | 3.678 |
| Pre-1990 (=1 if manufactured pre-1990) | 485.037 |
| Size (cubic feet) | 27.149 |
| Dummy: Side-by-Side (= 1 if side-by-side) | 406.779 |
| Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit) | 161.857 |
| Interaction: Located in Unconditioned Space x CDD/365.25 | 15.366 |
| Interaction: Located in Unconditioned Space x HDD/365.25 | -11.067 |

ΔkWh = [83.32 + (Age * 3.68) + (Pre-1990 * 485.04) + (Size * 27.15) + (Side-by-side * 406.78) + (Proportion of Primary Appliances * 161.86) + (CDD/365.25 * unconditioned * 15.37) + (HDD/365.25 *unconditioned *-11.07)] * Part Use Factor

Where:

Age = Age of retired unit

Pre-1990 = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)

Size = Capacity (cubic feet) of retired unit

Side-by-side = Side-by-side dummy (= 1 if side-by-side, else 0)

Primary Usage = Primary Usage Type (in absence of the program) dummy

(= 1 if Primary, else 0)

Interaction: Located in Unconditioned Space x CDD/365.25

(=1 * CDD/365.25 if in unconditioned space)

CDD = Cooling Degree Days

= Dependent on location[96]:

| Climate Zone (City based upon) | CDD 65 | CDD/365.25 |
|---|---|---|
| 1 (Rockford) | 820 | 2.25 |

[94] Based on the specified regression, a small number of units may have negative energy and demand consumption. These are a function of the unit size and age, and should comprise a very small fraction of the population. While on an individual basis this result is counterintuitive it is important that these negative results remain such that as a population the average savings is appropriate.

[95] Energy savings are based on an average 30-year TMY temperature of 51.1 degrees. Coefficients provided in July 30, 2014 memo from Cadmus: "Appliance Recycling Update no single door July 30 2014".

[96] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

| Climate Zone (City based upon) | CDD 65 | CDD/365.25 |
|---|---|---|
| 2 (Chicago) | 842 | 2.31 |
| 3 (Springfield) | 1,108 | 3.03 |
| 4 (Belleville) | 1,570 | 4.30 |
| 5 (Marion) | 1,370 | 3.75 |

Interaction: Located in Unconditioned Space x HDD/365.25

(=1 * HDD/365.25 if in unconditioned space)

HDD = Heating Degree Days

= Dependent on location:[97]

| Climate Zone (City based upon) | HDD 65 | HDD/365.25 |
|---|---|---|
| 1 (Rockford) | 6,569 | 17.98 |
| 2 (Chicago) | 6,339 | 17.36 |
| 3 (Springfield) | 5,497 | 15.05 |
| 4 (Belleville) | 4,379 | 11.99 |
| 5 (Marion) | 4,476 | 12.25 |

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used[98]. For illustration purposes, this example uses 0.93.[99]

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

ΔkWh = [83.32 + (22.81 * 3.68) + (0.45 * 485.04) + (18.82 * 27.15) + (0.17 * 406.78) + (0.34 * 161.86) + (1.29 * 15.37) + (6.49 * -11.07)] * 0.93

= 969 * 0.93

= 900.9 kWh

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients[100]:

| Independent Variable Description | Estimate Coefficient |
|---|---|
| Intercept | 132.122 |
| Age (years) | 12.130 |
| Pre-1990 (=1 if manufactured pre-1990) | 156.181 |
| Size (cubic feet) | 31.839 |
| Chest Freezer Configuration (=1 if chest freezer) | -19.709 |

[97] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

[98] For example, the part-use factor that shall be applied to the current program year t (PYt) for savings verification purposes should be determined through the PYt-2 participant surveys conducted in the respective utility's service territory, if available. If an evaluation was not performed in PYt-2 the latest available evaluation should be used.

[99] Most recent refrigerator part-use factor from Ameren Illinois PY5 evaluation.

[100] Energy savings are based on an average 30-year TMY temperature of 51.1 degrees. Coefficients provided in January 31, 2013 memo from Cadmus: "Appliance Recycling Update".

| Independent Variable Description | Estimate Coefficient |
|---|---|
| Interaction: Located in Unconditioned Space x CDD/365.25 | 9.778 |
| Interaction: Located in Unconditioned Space x HDD/365.25 | -12.755 |

ΔkWh = [132.12 + (Age * 12.13) + (Pre-1990 * 156.18) + (Size * 31.84) + (Chest Freezer * -19.71) + (CDDs* unconditioned *9.78) + (HDDs*unconditioned *-12.75)] * Part Use Factor

Where:

Age = Age of retired unit

Pre-1990 = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)

Size = Capacity (cubic feet) of retired unit

Chest Freezer = Chest Freezer dummy (= 1 if chest freezer, else 0)

Interaction: Located in Unconditioned Space x CDD/365.25

(=1 * CDD/365.25 if in unconditioned space)

CDD = Cooling Degree Days (see table above)

Interaction: Located in Unconditioned Space x HDD/365.25

(=1 * HDD/365.25 if in unconditioned space)

HDD = Heating Degree Days (see table above)

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used[101]. . For illustration purposes, the example uses 0.85.[102]

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

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

= 977 * 0.825

= 905 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = kWh/8766 * CF

Where:

kWh = Savings provided in algorithm above

CF = Coincident factor defined as summer kW/average kW

= 1.081 for Refrigerators

= 1.028 for Freezers[103]

---

[101] For example, the part-use factor that shall be applied to the current program year t (PYt) for savings verification purposes should be determined through the PYt-2 participant surveys conducted in the respective utility's service territory, if available. If an evaluation was not performed in PYt-2 the latest available evaluation should be used.

[102] Most recent freezer part-use factor from Ameren Illnois Company PY5 evaluation.

[103] Cadmus memo, February 12, 2013; "Appliance Recycling Update"

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

$$\Delta kW = 806/8766 * 1.081$$
$$= 0.099 \text{ kW}$$

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-RFRC-V07-190101**

**REVIEW DEADLINE: 1/1/2022**

## 5.1.9 Room Air Conditioner Recycling

### Description

This measure describes the savings resulting from running a drop off service taking existing residential, inefficient Room Air Conditioner units from service, prior to their natural end of life. This measure assumes that though a percentage of these units will be replaced this is not captured in the savings algorithm since it is unlikely that the incentive made someone retire a unit that they weren't already planning to retire. The savings therefore relate to the unit being taken off the grid as opposed to entering the secondary market. The Net to Gross factor applied to these units should incorporate adjustments that account for those participants who would have removed the unit from the grid anyway.

This measure was developed to be applicable to the following program types: ERET.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

N/A. This measure relates to the retiring of an existing inefficient unit.

### Definition of Baseline Equipment

The baseline condition is the existing inefficient room air conditioning unit.

### Deemed Lifetime of Efficient Equipment

The assumed remaining useful life of the existing room air conditioning unit being retired is 4 years[104].

### Deemed Measure Cost

The actual implementation cost for recycling the existing unit should be used.

### Loadshape

Loadshape R08 - Residential Cooling

### Coincidence Factor

The coincidence factor for this measure is assumed to be 30%[105].

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = ((FLH_{RoomAC} * Btu/hr * (1/EERexist))/1000)$$

Where:

$FLH_{RoomAC}$ = Full Load Hours of room air conditioning unit

= dependent on location[106]:

[104] A third of assumed measure life for Room AC.

[105] Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[106] The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air

| Climate Zone (City based upon) | $FLH_{RoomAC}$ |
|---|---|
| 1 (Rockford) | 220 |
| 2 (Chicago) | 210 |
| 3 (Springfield) | 319 |
| 4 (Belleville) | 428 |
| 5 (Marion) | 374 |
| Weighted Average[107] | 248 |

Btu/H = Size of retired unit

= Actual. If unknown assume 8500 Btu/hr [108]

EERexist = Efficiency of existing unit

= 9.8[109]

> For example for an 8500 Btu/h unit in Springfield:
>
> ΔkWh = ((319 * 8500 * (1/9.8)) / 1000)
>
> = 276 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (Btu/hr * (1/EERexist))/1000) * CF

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[110]

> For example an 8500 Btu/h unit:
>
> ΔkW = (8500 * (1/9.8)) / 1000) * 0.3
>
> = 0.26 kW

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

Conditioners, June 23, 2008) to FLH for Central Cooling for the same location is 31%. This ratio is applied to those IL cities that have FLH for Central Cooling provided in the ENERGY STAR calculator. For other cities this is extrapolated using the FLH assumptions VEIC have developed for Central AC. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

108 Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

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

110 Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-RARC-V02-190101**

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

## 5.1.10 ENERGY STAR Clothes Dryer

### Description

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR criteria. ENERGY STAR qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers[111]. ENERGY STAR provides criteria for both gas and electric clothes dryers.

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

### Definition of Efficient Equipment

Clothes dryer must meet the ENERGY STAR criteria, as required by the program.

### Definition of Baseline Equipment

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after January 1, 2015.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16 years[112].

### Deemed Measure Cost

The incremental cost for an ENERGY STAR clothes dryer is assumed to be $152[113]

### Loadshape

N/A

### Coincidence Factor

The coincidence factor for this measure is 3.8%[114].

[111] ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011.
[112] Based on DOE Rulemaking Technical Support Document, LCC Chapter, 2011, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[113] Based on the difference in installed cost for an efficient dryer ($716) and standard dryer ($564) (see "ACEEE Clothes Dryers.pdf").
[114] Based on coincidence factor of 3.8% for clothes washers

**Algorithm**

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = (Load/CEFbase – Load/CEFeff) * Ncycles * %Electric

Where:

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

| Dryer Size | Load (lbs)[115] |
|---|---|
| Standard | 8.45 |
| Compact | 3 |

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis[116]. If product class unknown, assume electric, standard.

| Product Class | CEF (lbs/kWh) |
|---|---|
| Vented Electric, Standard (≥ 4.4 $ft^3$) | 3.11 |
| Vented Electric, Compact (120V) (< 4.4 $ft^3$) | 3.01 |
| Vented Electric, Compact (240V) (<4.4 $ft^3$) | 2.73 |
| Ventless Electric, Compact (240V) (<4.4 $ft^3$) | 2.13 |
| Vented Gas | 2.84[117] |

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.[118] If product class unknown, assume electric, standard.

| Product Class | CEF (lbs/kWh) |
|---|---|
| Vented or Ventless Electric, Standard (≥ 4.4 $ft^3$) | 3.93 |
| Vented or Ventless Electric, Compact (120V) (< 4.4 $ft^3$) | 3.80 |
| Vented Electric, Compact (240V) (< 4.4 $ft^3$) | 3.45 |
| Ventless Electric, Compact (240V) (< 4.4 $ft^3$) | 2.68 |
| Vented Gas | 3.48[119] |

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year.[120]

%Electric = The percent of overall savings coming from electricity

115 Based on ENERGY STAR test procedures.

116 ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis

117 Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

118 ENERGY STAR Clothes Dryers Key Product Criteria.

119 Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

120 Appendix D to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Dryers.

= 100% for electric dryers, 16% for gas dryers[121]

| |
|---|
| Example<br>Time of Sale: For example, a standard, vented, electric clothes dryer:<br>ΔkWh = ((8.45/3.11 – 8.45/3.93) * 283 * 100%)<br>= 160 kWh |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer. Use actual data if available. If unknown, use 283 hours per year.[122]

CF = Summer Peak Coincidence Factor for measure

= 3.8%[123]

| |
|---|
| Example<br>Time of Sale: For example, a standard, vented, electric clothes dryer:<br>ΔkW = 160/283 * 3.8%<br>= 0.0215 kW |

**NATURAL GAS SAVINGS**

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

ΔTherm = (Load/EFbase – Load/CEFeff) * Ncycles * Therm_convert * %Gas

Where:

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

%Gas = Percent of overall savings coming from gas

= 0% for electric units and 84% for gas units[124]

[121] %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 16% was determined using a ratio of the electric to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.
[122] ENERGY STAR qualified dryers have a maximum test cycle time of 80 minutes. Assume one hour per dryer cycle.
[123] Based on coincidence factor of 3.8% for clothes washers.
[124] %Gas accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 84% was determined using a ratio of the gas to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

Example

Time of Sale: For example, a standard, vented, gas clothes dryer:

$$\Delta Therm = (8.45/2.84 - 8.45/3.48) * 283 * 0.03412 * 0.84$$

$$= 4.44 \text{ therms}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESDR-V02-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.1.11 ENERGY STAR Water Coolers

### Description

Water coolers are a home appliance that offer consumers the ability to enjoy hot and/or cold water on demand. This measure is the characterization of the purchasing and use of an ENERGY STAR certified water cooler in place of a conventional water cooler.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The high efficiency equipment is an ENERGY STAR certified water cooler meeting the ENERGY STAR 2.0 efficiency criteria.

### Definition of Baseline Equipment

The baseline equipment is a standard or conventional, non-ENERGY STAR certified water cooler.

### Deemed Lifetime of Efficient Equipment

The estimated useful life for a water cooler is 10 years[125].

### Deemed Measure Cost

The incremental cost for this measure is estimated at $17[126].

### Loadshape

Loadshape C53: Flat

### Coincidence Factor

The summer peak coincidence factor is assumed to be 1.0.

**Algorithm**

### Calculation of Energy Savings

### Electric Energy Savings

$$\Delta kWh = (kWh_{base} - kWh_{ee}) * Days$$

Where:

$kWh_{base}$ = Daily energy use (kWh/day) for baseline water cooler[127]

| Type of Water Cooler | kWhbase |
|---|---|
| Hot and Cold Water – Storage | 1.090 |
| Hot and Cold Water – On Demand | 0.330 |
| Cold Water Only | 0.290 |

[125] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
[126] Ameren Missouri PY3 Evaluation Report.
[127] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.

$kWh_{ee}$ = Daily energy use (kWh/day) for ENERGY STAR water cooler[128]

| Type of Water Cooler | kWhee |
|---|---|
| Hot and Cold Water – Storage | 0.747 |
| Hot and Cold Water – On Demand | 0.170 |
| Cold Water Only | 0.157 |

Days = Number of days per year that the water cooler is in use
= 365.25 days[129]

Energy Savings:

| Type of Water Cooler | ΔkWh |
|---|---|
| Hot and Cold Water – Storage | 125.4 |
| Hot and Cold Water – On Demand | 58.4 |
| Cold Water Only | 48.7 |

**DEMAND SAVINGS**

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

Where:

Hours = Number of hours per year water cooler is in use
= 8766 hours[130]

CF = Summer Peak Coincidence Factor for measure

= 1.0

Demand Savings:

| Type of Water Cooler | ΔkW |
|---|---|
| Hot and Cold Water - Storage | 0.0143 |
| Hot and Cold Water – On Demand | 0.0067 |
| Cold Water Only | 0.0056 |

**NATURAL GAS SAVINGS**

N/A

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

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

[128] Average kWh/day for from the ENERGY STAR efficient product database.
[129] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
[130] Assumed 365 days per year and 24 hours per day as utilized in daily energy consumption from ENERGY STAR Program Requirements Product Specification for Water Coolers Test Method.

**MEASURE CODE: RS-APL-WTCL-V01-180101**

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

## 5.1.12 Ozone Laundry

**DESCRIPTION**

A new ozone laundry system is added-on to new or existing residential clothes washing machine(s) currently using hot water heated with natural gas. The system generates ozone ($O_3$), a naturally occurring molecule, which helps clean fabrics by chemically reacting with soils in cold water. Adding an ozone laundry system(s) eliminate the use of chemicals, detergents, and hot water by residential washing machine(s).

Energy savings will be achieved at the domestic hot water heater as it will no longer supply hot water to the washing machine. Cold water usage by the clothes washer will increase, but overall water usage will stay constant.

This measure was developed to be applicable to the following program types: TOS, RNC, RF

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

A new, packaged ozone laundry system(s) rated for residential clothes washing machines is added-on to new or existing residential clothes washing machines. The ozone laundry system must be connected to both the hot and cold water inlets of the clothes washing machine so that hot water from the domestic hot water heater is no longer provided to the clothes washer.

The ozone laundry system(s) must transfer ozone into the water through:

- Venturi injection
- Bubble diffusion
- Additional applications may be considered upon program review and approval on a case by case basis

**DEFINITION OF BASELINE EQUIPMENT**

The base case equipment is a conventional residential washing machine with no ozone generator installed. The washing machine is provided hot water from a domestic hot water heater.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure equipment effective useful life (EUL) is estimated at 8 years based on the typical lifetime of products currently available in the market.[131]

**DEEMED MEASURE COST**

The deemed measure cost is $300 for a new residential ozone laundry system[132]

**LOADSHAPE**

Loadshape R01 – Residential Clothes Washer

**COINCIDENCE FACTOR**

The coincidence factor for this measure is 3.8%[133].

[131] Average based on conversations with manufacturers and distributors of the four residential ozone laundry systems tested in the 2018 GTI Residential Ozone Laundry Field Demonstration (O3 Pure, Pure Wash, Eco Washer, Scent Crusher).
[132] 2018 GTI Residential Ozone Laundry Field Demonstration (May 2018).
[133] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = kWhHotWash * (\%HotWash_{base} - \%HotWash_{Ozone})$$

Where:

kWhHotWash = (%ElectricDHW * Capacity * IWF * %HotWater * ($T_{OUT}$ - $T_{IN}$) * 8.33 * 1.0 * Ncycles) / (RE_electric * 3.412)

%ElectricDHW = Proportion of water heating supplied by electric heating

| DHW fuel | %FossilDHW |
|---|---|
| Electric | 100% |
| Natural gas | 0% |
| Unknown | 16%[134] |

Capacity = Clothes washer capacity (cubic feet).

= Actual. If unknown, assume 4.96 cubic feet.[135]

IWF = Integrated water factor (gallons/cycle/$ft^3$).

= Actual. If unknown, use the following values:

| Efficiency Level | IWF (gallons/cycle/ft3 | |
|---|---|---|
| | Top loading > 2.5 Cu ft | Front Loading > 2.5 Cu ft |
| Federal Standard (as of March 2015) | 8.4 | 4.7 |
| ENERGY STAR (as of February 2018) | 4.3 | 3.2 |
| CEE Tier 3 | 3.2 | 3.2 |

%HotWater = Percentage of water usage that is supplied by the domestic hot water heater when the hot or warm wash cycles are selected.

= 0.1757[136]

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municipal system

[134] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[135] Average data from GTI Residential Ozone Laundry Field Demonstration (May 2018). As an add on to existing equipment it is assumed this is a larger capacity than the assumption for new Clothes Washers as old machines tended to have larger capacities. See 'Residential Ozone Summary Calcs – May2018.xls' for more information. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[136] Averaged data from GTI Residential Ozone Laundry Field Demonstration (May 2018). Hot and warm wash cycles were combined because data from the EIA Resicential Energy Consumption Survey (RECS) 2015 East North Central Region show that, of the total hot and warm washes that occur, over 96% are warm washes. See 'Residential Ozone Summary Calcs – May2018.xls' for more information.

= 54.1°F[137]

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat capacity of water (Btu/lb °F)

Ncycles = Number of Cycles per year

= 264[138]

RE_electric = Recovery efficiency of electric water heater

= 98% [139]

3412 = Btus to kWh conversion (Btu/kWh)

$\%HotWash_{base}$ = Average percentage of loads that use hot or warm water with baseline equipment.

= 0.7743[140]

$\%HotWash_{Ozone}$ = Percentage of loads that use hot or warm water with efficient equipment.

= 0.0

For example, a residential ozone laundry system is installed in a single family home with an electric domestic hot water heater. The capacity and IWF of the baseline equipment is unknown.

ΔkWh = (1 * 4.96 * 8.4 * 0.1757 * (125 – 54.1) * 8.33 * 1.0 * 264) / (0.98 * 3412) * (0.7743 – 0)

= 264 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Assumed Run hours of Clothes Washer

= 264 hours[141]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[142]

For example, a residential ozone laundry system is installed in a single family home with an electric domestic hot water heater. The capacity and IWF of the baseline equipment is unknown.

ΔkW = 264/264 * 0.038

= 0.038kW

[137] US DOE Building America Program. Building America Analysis Spreadsheet.

[138] Weighted average of clothes washer cycles per year (based on 2015 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, West North Central Census Division
If utilities have specific evaluation results providing a more appropriate assumption for single-family or Multifamily homes, in a particular market, or geographical area then that should be used.

[139] Electric water heaters have recovery efficiency of 98%.

[140] GTI Residential Ozone Laundry Field Demonstration (May 2018). See 'Residential Ozone Summary Calcs – May2018.xls' for more information.

[141] Based on a weighted average of 264 clothes washer cycles per year assuming an average load runs for one hour.

[142] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

### NATURAL GAS SAVINGS

$$\Delta Therm = ThermHotWash * (\%HotWash_{base} - \%HotWash_{Ozone})$$

Where:

ThermHotWash = (%FossilDHW * Capacity * IWF * %HotWater * ($T_{OUT}$ - $T_{IN}$) * 8.33 * 1.0 * Ncycles) / (RE_gas * 100,000)

%FossilDHW = proportion of water heating supplied by natural gas heating

| DHW fuel | %FossilDHW |
|---|---|
| Electric | 0% |
| Natural gas | 100% |
| Unknown | 84%[143] |

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[144]

= 67% For MF homes[145]

100,000 = Btus to Therms conversion (Btu/Therm).

For example, a residential ozone laundry system is installed in a single family home with a gas domestic hot water heater. The capacity and IWF of the baseline equipment is unknown.

ΔTherms = (1 * 4.96 * 8.4 * 0.1757 * (125 – 54.1) * 8.33 * 1.0 * 264) / (0.78 * 100,000) * (0.7743 – 0)

= 11.32 Therms

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

#### LAUNDRY DETERGENT SAVINGS

Annual savings from not purchasing laundry detergent that are realized by efficient equipment end-user(s) ($/year).

Detergent savings per year = Detergent_cost * Ncycles

Where:

Detergent_cost = Average laundry detergent cost per load ($/load).

[143] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[144] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[145] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

= 0.16[146]

| |
|---|
| For example, a residential ozone laundry system is installed in a single family home.<br>Detergent savings per year = 0.16 * 295<br>= $47.2 |

**MEASURE CODE: RS-APL-OZNE-V01-190101**

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

[146] Based on cost analysis of products available on www.Jet.com and www.Amazon.com.

## 5.2 Consumer Electronics End Use

### 5.2.1 Advanced Power Strip – Tier 1

#### DESCRIPTION

This measure relates to Advanced Power Strips – Tier 1 which are multi-plug surge protector power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it. This measure characterization provides savings for a 5-plug strip and a 7-plug strip.

This measure was developed to be applicable to the following program types: TOS, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

#### DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is the use of a 5 or 7-plug advanced power strip.

#### DEFINITION OF BASELINE EQUIPMENT

For time of sale or new construction applications, the assumed baseline is a standard power strip that does not control connected loads.

For direct install and kits, the baseline is the existing equipment utilized in the home.

#### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the advanced power strip is 7 years[147].

#### 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[148].

For direct install the actual full install cost (including labor) and for kits the full equipment cost should be used.

#### LOADSHAPE

Loadshape R13 - Residential Standby Losses – Entertainment

Loadshape R14 - Residential Standby Losses - Home Office

#### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 80%[149].

**Algorithm**

[147] This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2.

[148] Price survey performed by Illume Advising LLC for IL TRM workpaper, see “Current Surge Protector Costs and Comparison 7-2016” spreadsheet.

[149] 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.

### 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[150]

ISR = In Service Rate, dependent on delivery mechanism

| Delivery Mechanism | ISR |
|---|---|
| Energy Efficiency Kit, Leave behind | 69%[151] |
| Direct Install, Time of Sale | 100% |

Using assumptions above:

| # Plugs | Delivery Mechanism | ΔkWh |
|---|---|---|
| 5- plug | Energy Efficiency Kit, Leave behind | 39.0 |
| | Direct Install, Time of Sale | 56.5 |
| 7-plug | Energy Efficiency Kit, Leave behind | 71.1 |
| | Direct Install, Time of Sale | 103.0 |
| Unknown[152] | Energy Efficiency Kit, Leave behind | 55.0 |
| | Direct Install, Time of Sale | 80.0 |

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / 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 [153]

CF = Summer Peak Coincidence Factor for measure

[150] 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.

[151] Average of Ameren Missouri, Potomac Edison, and PPL Electric ISR for smart strips in kits.
Cadmus, "Ameren Missouri RebateSavers Impact and Process Evaluation: Program Year 2013" p. 75.
Cadmus, "Process Evaluation Report, PPL Electric EE&C Plan, Program Year Five." p. 94
"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.

[152] Calculated as average of 5 and 7 plug savings assumptions.

[153] Average of hours for controlled TV and computer from; NYSERDA Measure Characterization for Advanced Power Strips

= 0.8 [154]

| # Plugs | Delivery Mechanism | ΔkW |
|---|---|---|
| 5- plug | Energy Efficiency Kit, Leave behind | 0.0044 |
| | Direct Install, Time of Sale | 0.0063 |
| 7-plug | Energy Efficiency Kit, Leave behind | 0.0080 |
| | Direct Install, Time of Sale | 0.0116 |
| Unknown [155] | Energy Efficiency Kit, Leave behind | 0.0062 |
| | Direct Install, Time of Sale | 0.0090 |

**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-V04-190101**

**REVIEW DEADLINE: 1/1/2021**

[154] 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.
[155] Calculated as average of 5 and 7 plug savings assumptions.

## 5.2.2 Tier 2 Advanced Power Strips (APS) – Residential Audio Visual

### Description

This measure relates to the installation of a Tier 2 Advanced Power Strip / surge protector for household audio visual environments (Tier 2 AV APS). Tier 2 AV APS are multi-plug power strips that remove power from audio visual equipment through intelligent control and monitoring strategies.

By utilizing advanced control strategies such as a countdown timer, external sensors (e.g. of infra-red remote usage and/or occupancy sensors, true RMS (Root Mean Square) power sensing; both active power loads and standby power loads of controlled devices are managed by Tier 2 AV APS devices[156]. Monitoring and controlling both active and standby power loads of controlled devices will reduce the overall load of a centralized group of electrical equipment (i.e. the home entertainment center). This more intelligent sensing and control process has been demonstrated to deliver increased energy savings and demand reduction compared with 'Tier 1 Advanced Power Strips'.

The Tier 2 APS market is a relatively new and developing one. With several new Tier 2 APS products coming to market, it is important that energy savings are clearly demonstrated through independent field trials. The IL Technical Advisory Committee have developed a protocol whereby product manufacturers must submit independent field trial evidence of the Energy Reduction Percentage of their particular product either to the TRM Administrator for consideration during the TRM update process (August – December), or engage with a Program Administrator's independent evaluation team to review at other times. The product will be assigned a Product Class (A-H) corresponding to the proven savings and all products in a class will claim consistent savings. The IL TRM Administrator will maintain a list of eligible product and class on the IL TRM Sharepoint site. If a mid-year review has taken place, supporting information should be posted on the Sharepoint site such that other program administrators can review.

Due to the inherent variance day to day and week to week for hours of use of AV systems, it is critical that field trial studies effectively address the variability in usage patterns. There is significant discussion in the EM&V and academic domain on the optimal methodology for controlling for these factors and in submitting evidence of energy savings, it is critical that it is demonstrated that these issues are adequately addressed.

This measure was developed to be applicable to the following program types: DI. If applied to other program delivery types, the installation characteristics including the number of AV devices under control and an appropriate in service rate should be verified through evaluation.

Current evaluation is limited to Direct Install applications. Through a Direct Install program it can be assured that the APS is appropriately set up and the customer is knowledgeable about its function and benefit. It is encouraged that additional implementation strategies are evaluated to provide an indication of whether the units are appropriately set up, used with AV equipment and that the customer is knowledgeable about its function and benefit. This will then facilitate a basis for broadening out the deployment methods of the APS technology category beyond Direct Install.

### Definition of Efficient Equipment

The efficient case is the use of a Tier 2 AV APS in a residential AV (home entertainment) environment that includes control of at least 2 AV devices with one being the television[157].

Only Tier 2 AV APS products that have independent demonstrated energy savings via field trials are eligible.

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[156] Tier 2 AV APS identify when people are not engaged with their AV equipment and then remove power, for example a TV and its peripheral devices that are unintentionally left on when a person leaves the house or for instance where someone falls asleep while watching television.

[157] Given this requirement, an AV environment consisting of a television and DVD player or a TV and home theater would be eligible for a Tier 2 AV APS installation.

The minimum product specifications for Tier 2 AV APS are:

**Safety & longevity**

- Product and installation instructions shall comply with 2012 International Fire Code and 2000 NFPA 101 Life Safety Code (IL Fire Code).
- Third party tested to all applicable UL Standards.
- Contains a resettable circuit breaker
- Incorporates power switching electromechanical relays rated for 100,000 switching cycles at full 15 amp load (equivalent to more than 10 years of use).

**Energy efficiency functionality**

- Calculates real power as the time average of the instantaneous power, where instantaneous power is the product of instantaneous voltage and current.
- Delivers a warning when the countdown timer begins before an active power down event and maintains the warning until countdown is concluded or reset by use of the remote or other specified signal
- Uses an automatically adjustable power switching threshold.

### Definition of Baseline Equipment

The assumed baseline equipment is the existing equipment being used in the home (e.g. a standard power strip or wall socket) that does not control loads of connected AV equipment.

### Deemed Lifetime of Efficient Equipment

The default deemed lifetime value for Tier 2 AV APS is assumed to be 7 years[158].

### Deemed Measure Cost

Direct Installation: The actual installed cost (including labor) of the new Tier 2 AV APS equipment should be used.

### Loadshape

Loadshape R13 - Residential Standby Losses – Entertainment

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 80%[159]

## Algorithm

### Calculation of Energy Savings

### Electric Energy Savings

$$\Delta kWh = ERP * BaselineEnergy_{AV} * ISR$$

Where:

ERP = Energy Reduction Percentage of qualifying Tier2 AV APS product range as provided below. See reference documents for Product Classification memo.

[158] There is little evaluation to base a lifetime estimate upon. Based on review of assumptions from other jurisdictions and the relative treatment of In Service Rates and persistence, an estimate of 7 years was agreed by the Technical Advisory Committee, but further evaluation is recommended.

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

| Product Class | Field trial ERP range | ERP used |
|---|---|---|
| A | 55 – 60% | 55% |
| B | 50 – 54% | 50% |
| C | 45 – 49% | 45% |
| D | 40 – 44% | 40% |
| E | 35 – 39% | 35% |
| F | 30 – 34% | 30% |
| G | 25 – 29% | 25% |
| H | 20 – 24% | 20% |

$BaselineEnergy_{AV}$ = 432 kWh[160]

ISR = In Service Rate. See reference documents for Product Classification memo.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / Hours * CF

Where:

ΔkWh = Energy savings as calculated above

Hours = Annual number of hours during which the APS provides savings.

= 4,380 [161]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [162]

**NATURAL GAS SAVINGS**

N/A[163]

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

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-CEL-APS2-V03-190101**

**REVIEW DEADLINE: 1/1/2020**

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160 AESC, Inc, "Energy Savings of Tier 2 Advanced Power Strips in Residential AC Systems", p28. Note that this load represents the average *controlled* AV devices only and will likely be lower than total AC usage.

161 This is estimate based on assumption that approximately half of savings are during active hours (supported by AESC study) (assumed to be 5.3 hrs/day, 1936 per year (NYSERDA 2011. "*Advanced Power Strip Research Report*")) and half during standby hours (8760-1936 = 6824 hours). The weighted average is 4380.

162 In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes. This appears to be supported by the Average Weekday AV Demand Profile and Reduction charts in the AESC study (p33-34). These show that the average demand reduction is relatively flat.

163 Interactive effects of Tier 2 APS on space conditioning loads has not yet been adequately studied.

## 5.3 HVAC End Use

### 5.3.1 Air Source Heat Pump

**DESCRIPTION**

A heat pump provides heating or cooling by moving heat between indoor and outdoor air.

This measure characterizes:

a) Time of Sale:

- The installation of a new residential sized (<= 65,000 Btu/hr) air source heat pump that is more efficient than required by federal standards. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

The early removal of functioning electric heating and cooling (SEER 10 or under if present) systems from service, prior to its natural end of life, and replacement with a new high efficiency air source heat pump unit.

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<$276 per ton)[164].
- All other conditions will be considered Time of Sale.

The Baseline SEER of the existing unit replaced:

- If the SEER of the existing unit is known and <=10, the Baseline SEER is the actual SEER value of the unit replaced. If the SEER is >10, the Baseline SEER = 14.
- If the SEER of the existing unit is unknown use assumptions in variable list below (SEER_exist and HSPF_exist).
- If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown.[165]

**Deemed Early Replacement Rates For ASHP**

| | Deemed Early Replacement Rate |
|---|---|
| Early Replacement Rate for ASHP participants | 7% |

Note it is not appropriate to claim additional ECM fan savings (from 5.3.5 Furnace Blower Motor) due to installing new ASHP units with an ECM, since the SEER/EER/HSPF ratings already account for this electrical load.

Quality Installation:

[164] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[165] Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. This is used as a reasonable proxy for ASHP installations since ASHP specific data is not available. Report presented to Nicor Gas Company February 27, 2014.

Additional savings are attributed to the Quality Installation (QI) of the system. QI programs should follow industry standards such as those described in ENERGY STAR Verified HVAC Installation Program (ESVI), ANSI ACCA QI5 and QI9vp. This must include considerations of system design (including sizing, matching, ventilation calculations) and equipment installation (including static pressure, airflow, refrigerant charge) and may also consider distribution.

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

### Definition of Efficient Equipment

A new residential sized (<= 65,000 Btu/hr) air source heat pump with specifications to be determined by program.

### Definition of Baseline Equipment

A new residential sized (<= 65,000 Btu/hr) air source heat pump meeting federal standards.

The baseline for the Time of Sale measure is based on the current Federal Standard efficiency level as of January 1st 2015; 14 SEER and 8.2HSPF an estimate of expected peak rated efficiency of 11.

The baseline for the early replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16 years.[166]

Remaining life of existing ASHP/CAC equipment is assumed to be 6 years[167] and 18 years for electric resistance.

### Deemed Measure Cost

Time of sale: The incremental capital cost for this measure is dependent on the efficiency of the new unit[168].

| Efficiency (SEER) | Incremental Cost ($/unit) |
|---|---|
| 14.5 | $123 |
| 15 | $303 |
| 16 | $438 |
| 17 | $724 |
| 18 | $724 |

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume the following (note these costs are per ton of unit capacity)[169]:

| Efficiency (SEER) | Full Retrofit Cost (including labor) |
|---|---|
| 14.5 | $1,381 / ton + $123 |
| 15 | $1,381 / ton + $303 |
| 16 | $1,381 / ton + $438 |
| 17 | $1,381 / ton + $724 |
| 18 | $1,381 / ton + $724 |

[166] Based on 2016 DOE Rulemaking Technical Support document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[167] Assumed to be one third of effective useful life
[168] Based on incremental cost results from Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016.
[169] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation. Efficiency cost increment consistent with Cadmus study results.

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $1,518 per ton of capacity[170]. This cost should be discounted to present value using the nominal societal discount rate.

Quality Installation: The additional design and installation work associated with quality installation has been estimated to cost an additional $150[171].

**LOADSHAPE**

Loadshape R10 - Residential Electric Heating and Cooling

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP\ SF}$ = Summer System Peak Coincidence Factor for Heat Pumps in single-family homes (during utility peak hour)

= 72%[172]

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

= 46.6%[173]

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

= 67%[174]

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

= 28.5%

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Time of sale:

$$\Delta kWh = ((FLH\_cooling * Capacity\_cooling * (1/(SEER\_base * (1 – DeratingCool_{Base})) - 1/(SEER\_ee * SEERadj * (1 – DeratingCool_{Eff})))) / 1000) + ((FLH\_heat * Capacity\_heating * (1/(HSPF\_base * (1 – DeratingHeat_{Base})) - 1/(HSPF\_ee * HSPFadj * (1 – DeratingHeat_{Eff})))) / 1000)$$

Early replacement[175]:

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170 Ibid. $1381 per ton inflated using rate of 1.91%.

171 Based on data provided by Mid American in April 2018 summarizing survey results from 11 HVAC suppliers in Iowa.

172 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)'.

173 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.

174 Multifamily coincidence factors both from; *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015

175 The two equations are provided to show how savings are determined during the initial phase of the measure (existing to

ΔkWH for remaining life of existing unit (1st 6 years for replacing an ASHP, 18 years for replacing electric resistance):

= ((FLH_cooling * Capacity_cooling * (1/(SEER_exist * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$)))) / 1000) + ((FLH_heat * Capacity_heating * (1/(HSPF_exist * (1 – $DeratingHeat_{Base}$)) - 1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) / 1000)

ΔkWH for remaining measure life (next 12 years if replacing an ASHP):

= ((FLH_cooling * Capacity_cooling * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$)))) / 1000) + ((FLH_heat * Capacity_heating * (1/(HSPF_base * (1 – $DeratingHeat_{Base}$)) - 1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) / 1000)

Where:

FLH_cooling = Full load hours of air conditioning

= dependent on location:

| Climate Zone (City based upon) | FLH_cooling (single family) [176] | FLH_cooling (general multifamily) [177] | FLH_cooling (weatherized multifamily) [178] |
|---|---|---|---|
| 1 (Rockford) | 512 | 467 | 299 |
| 2 (Chicago) | 570 | 506 | 324 |
| 3 (Springfield) | 730 | 663 | 425 |
| 4 (Belleville) | 1,035 | 940 | 603 |
| 5 (Marion) | 903 | 820 | 526 |
| Weighted Average[179] | 629 | 564 | 362 |

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

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

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

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

= Use actual SEER rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year to account for degradation over time[180], or use defaults provided below:

| Existing Cooling System | SEER_exist[181] |
|---|---|
| Air Source Heat Pump | 9.3 |

efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

[176] 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.

[177] Ibid.

[178] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. The multifamily units within this study had undergone significant shell improvements (air sealing and insulation) and therefore this set of assumptions is only appropriate for units that have recently participated in a weatherization or other shell program. Note that the FLHcool where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

[179] Weighted based on number of occupied residential housing units in each zone.

[180] Justification for degradation factors can be found on page 21 of ‘AIC HVAC Metering Study Memo FINAL 2_28_2018’

[181] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See ‘AIC HVAC Metering Study Memo FINAL 2_28_2018’.

| Existing Cooling System | SEER_exist[181] |
|---|---|
| Central AC | |
| No central cooling[182] | Make '1/SEER_exist' = 0 |

SEER_base = Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)

= 14 [183]

SEER_ee = Rated Seasonal Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh)

= Actual, or 15 if unknown.

SEERadj = Adjustment percentage to account for in-situ performance of the unit

= $[(0.805 \times \left(\frac{EER_{ee}}{SEER_{ee}}\right) + 0.367]$

$DeratingCool_{Eff}$ = Efficent ASHP Cooling derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown[185]

$DeratingCool_{Base}$ = Baseline Cooling derating

= 10%

FLH_heat = Full load hours of heating

= Dependent on location and home type:

| Climate Zone (City based upon) | FLH_heat (single family and general multifamily)[186] | FLH heat (weatherized multifamily)[187] |
|---|---|---|
| 1 (Rockford) | 1,969 | 748 |
| 2 (Chicago) | 1,840 | 699 |
| 3 (Springfield) | 1,754 | 667 |
| 4 (Belleville) | 1,266 | 481 |
| 5 (Marion) | 1,288 | 489 |
| Weighted Average[188] | 1,821 | 692 |

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

[183] Based on Minimum Federal Standard effective 1/1/2015.

[184] In situ performance based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[185] Based on Cadmus assumption provided in preparation of the 2014 Interstate Power and Light TRM based upon proper refrigerant charge, evaporator airflow, and unit sizing, Appears conservative in comparison to ENERGY STAR statements (see 'Sponsoring an ENERGY STAR Verified HVAC Installation (ESVI) Program'). Note pending ComEd evaluation will provide an update to these assumptions.

[186] Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the ENERGY STAR Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider ENERGY STAR estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from ICC commerce Commission) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the ENERGY STAR data (1994 hours) to scale down the ENERGY STAR estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[187] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015.

[188] Weighted based on number of occupied residential housing units in each zone.

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

Capacity_heating = Heating Capacity of Air Source Heat Pump (Btu/hr)

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

HSPF_exist =Heating System Performance Factor[189] of existing heating system (kBtu/kWh)

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If not available use:

| Existing Heating System | HSPF_exist |
|---|---|
| Air Source Heat Pump | 5.54 [190] |
| Electric Resistance | 3.41[191] |

HSPF_base =Heating System Performance Factor of baseline Air Source Heat Pump (kBtu/kWh)

= 8.2 [192]

HSPF_ee =Heating System Performance Factor of efficient Air Source Heat Pump

(kBtu/kWh)

= Actual or 8.5 if unknown

HSPFadj = Adjustment percentage to account for in-situ performance of the unit

$= \left[\left(\frac{17\,°F\ Capacity}{47\,°F\ Capacity}\right) \times 0.158 + 0.899\right]$

$DeratingHeat_{Eff}$ = Efficent ASHP Heating derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed[194]

$DeratingHeat_{Base}$ = Baseline Heatin derating

= 10%

[189] HSPF ratings for Heat Pumps account for the seasonal average efficiency of the units and are based on testing within zone 4 which encompasses most of Illinois. Furthermore, a recent Cadmus/Opinion Dynamics metering study, "Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)", found no significant variance between metered performance and that presented in the TRM

[190] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[191] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.

[192] Based on Minimum Federal Standard effective 1/1/2015.

[193] In situ performance based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[194] Based on Cadmus assumption provided in preparation of the 2014 Interstate Power and Light TRM based upon proper refrigerant charge, evaporator airflow, and unit sizing, Assumed consistent for heating and cooling. Appears conservative in comparison to ENERGY STAR statements (see 'Sponsoring an ENERGY STAR Verified HVAC Installation (ESVI) Program'). Note pending ComEd evaluation will provide an update to these assumptions.

Time of Sale:

For example, an ASHP is installed in a single-family home in Marion with the following nameplate information: 15 SEER, 12EER, 9 HSPF; Cooling capacity: 34,800 Btuh; Heating capacity at 47°F: 33,000 Btuh; Heating capacity at 17°F: 21,200 Btuh with Quality Installation;

$$\%\,SEER_{adj} = 0.805 \times \left(\frac{EER_{ee}}{SEER_{ee}}\right) + 0.367 = 1.011$$

$$\%\,HSPF_{adj} = \left(\frac{17\,°F\ Capacity}{47\,°F\ Capacity}\right) \times 0.158 + 0.899 = 1.001$$

ΔkWh = ((903 * 34,800 * (1/(14 * (1 - 0.1)) - 1/(15 * 1.011 * (1 – 0)))) / 1000) + ((1,288 * 33,000 * (1/(8.2 * (1 – 0.1)) - 1/(9 * 1.001 * (1-0)))) / 1000)

= 1463 kWh

Early Replacement:

For example, a 15 SEER, 12EER, 9 HSPF Air Source Heat Pump with nameplate information as above replaces an existing working Air Source Heat Pump with unknown efficiency ratings in a single family home in Marion:

ΔkWH for remaining life of existing unit (1st 6 years):

= ((903 * 34,800 * (1/(9.3 * (1-0.1)) - 1/(15 * 1.011 * (1-0)))) / 1000) + ((1,288 * 33,000 * (1/(5.54 * (1-0.1)) - 1/(9 * 1.001 * (1-0)))) / 1000)

= 5489 kWh

ΔkWH for remaining measure life (next 12 years):

= ((903 * 34,800 * (1/(14 * (1 - 0.1)) - 1/(15 * 1.011 * (1 – 0)))) / 1000) + ((1,288 * 33,000 * (1/(8.2 * (1 – 0.1)) - 1/(9 * 1.001 * (1-0)))) / 1000)

= 1463 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Time of sale:

ΔkW = (Capacity_cooling * (1/(EER_base * (1 – $DeratingCool_{Base}$)) - 1/(EER_ee * (1 – $DeratingCool_{Eff}$)))) / 1000 * CF

Early replacement[195]:

ΔkW for remaining life of existing unit (1st 6 years for replacing an ASHP, 18 years for replacing electric resistance):

= (Capacity_cooling * (1/(EERexist * (1 – $DeratingCool_{Base}$)) - 1/(EERee * (1 – $DeratingCool_{Eff}$)))) / 1000 * CF

ΔkW for remaining measure life (next 12 years if replacing an ASHP):

= (Capacity_cooling * (1/(EER_base * (1 – $DeratingCool_{Base}$)) - 1/(EER_ee * (1 – $DeratingCool_{Eff}$)))) / 1000 * CF

Where:

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

= Use actual EER rating where it is possible to measure or reasonably estimate. If using

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

rated efficiencies, derate efficiency value by 1% per year to account for degradation over time[196], or use defaults provided below:

| Existing Cooling System | EER_exist[197] |
|---|---|
| Air Source Heat Pump | 7.5 |
| Central AC | |
| No central cooling[198] | Make '1/EER_exist' = 0 |

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

= 11 [199]

EER_ee = Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/hr / kW)

= Actual. If unknown assume 12.5 EER.

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

= 72%%[200]

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

= 46.6%[201]

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

= 67%[202]

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

= 28.5%[35]

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

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[196] Justification for degradation factors can be found on page 21 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

[197] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

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

[199] The Federal Standard does not include an EER requirement. The value provided is based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[200] 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)'.

[201] 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.

[202] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015

Time of Sale:

For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump installed in single-family home in Marion with Quality Installation:

$\Delta kW_{SSP}$ = (36,000 * (1/(11 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.72

= 0.458 kW

$\Delta kW_{PJM}$ = (36,000 * (1/(11 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 0.297 kW

Early Replacement:

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

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

= (36,000 * (1/(7.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.72

= 1.68 kW

$\Delta kW_{SSP}$ for remaining measure life (next 12 years):

= (36,000 * (1/(11 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.72

= 0.458 kW

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

= (36,000 * (1/(7.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.466

= 1.087 kW

$\Delta kW_{PJM}$ for remaining measure life (next 12 years):

= (36,000 * (1/(11 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 0.297 kW

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-ASHP-V08-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.3.2 Boiler Pipe Insulation

#### DESCRIPTION

This measure describes adding insulation to un-insulated boiler pipes in un-conditioned basements or crawlspaces.

This measure was developed to be applicable to the following program types: TOS, RNC, RF, DI.

If applied to other program types, the measure savings should be verified.

#### DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is installing pipe wrap insulation to a length of boiler pipe.

#### DEFINITION OF BASELINE EQUIPMENT

The baseline is an un-insulated boiler pipe.

#### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years[203].

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 13 years[204]. See section below for detail.

#### DEEMED MEASURE COST

The measure cost including material and installation is assumed to be $3 per linear foot[205].

#### LOADSHAPE

N/A

#### COINCIDENCE FACTOR

N/A

**Algorithm**

#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

N/A

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

#### NATURAL GAS SAVINGS

$$\Delta Therm = (((1/R_{exist} * C_{exist}) - (1/R_{new} * C_{new})) * FLH\_heat * L * \Delta T) / \eta Boiler / 100,000$$

[203] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[204] 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.
[205] Consistent with DEER 2008 Database Technology and Measure Cost Data.

Where:

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

= 0.5[206]

$R_{new}$ = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft$^2$)/Btu]

= Actual (0.5 + R value of insulation)

FLH_heat = Full load hours of heating

= Dependent on location[207]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[208] | 1,821 |

L = Length of boiler pipe in unconditioned space covered by pipe wrap (ft)

= Actual

$C_{exist}$ = Circumference of bare pipe (ft) (Diameter (in) * π/12)

= Actual (0.5” pipe = 0.131ft, 0.75” pipe = 0.196ft)

$C_{new}$ = Circumference of pipe with insulation (ft) ([Diameter of pipe (in)] + ([Thickness of Insulation (in)]*2)) * π/12)

= Actual

ΔT = Average temperature difference between circulated heated water and unconditioned space air temperature (°F) [209]

Pipes in unconditioned basement:

| Outdoor reset controls | ΔT (°F) |
|---|---|
| Boiler without reset control | 110 |
| Boiler with reset control | 70 |

206 Assumption based on data obtained from the 3E Plus heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association) and derived from Table 15 and Table 16 of 2009 ASHRAE Fundamentals Handbook, Chapter 23 Insulation for Mechanical Systems, page 23.17.

207 Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the ENERGY STAR Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider ENERGY STAR estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from Illinois Commerce Commission) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the ENERGY STAR data (1994 hours) to scale down the ENERGY STARr estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

209 Assumes 160°F water temp for a boiler without reset control, 120°F for a boiler with reset control, and 50°F air temperature for pipes in unconditioned basements and the following average heating season outdoor temperatures as the air temperature in crawl spaces: Zone 1 – 33.1, Zone 2 – 34.4, Zone 3 – 37.7, Zone 4 – 40.0, Zone 5 – 39.8, Weighted Average – 35.3 (NCDC 1881-2010 Normals, average of monthly averages Nov – Apr for zones 1-3 and Nov-March for zones 4 and 5).

Pipes in crawl space:

| Climate Zone (City based upon) | ΔT (°F) | |
|---|---|---|
| | Boiler without reset control | Boiler with reset control |
| 1 (Rockford) | 127 | 87 |
| 2 (Chicago) | 126 | 86 |
| 3 (Springfield) | 122 | 82 |
| 4 (Belleville) | 120 | 80 |
| 5 (Marion) | 120 | 80 |
| Weighted Average[210] | 125 | 85 |

ηBoiler = Efficiency of boiler

= 0.819 [211]

For example, insulating 10 feet of 0.75" pipe with R-3 wrap (0.75" thickness) in a crawl space of a Marion home with a boiler without reset control:

ΔTherm = (((1/0.5 * 0.196) – (1/3.5 * 0.589)) * 10 * 120 * 1288) / 0.819 / 100,067

= 4.2 therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating 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 |
|---|---|---|
| ηHeat | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 13 years[212].

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[210] Weighted based on number of occupied residential housing units in each zone.
[211] Average efficiency of boiler units found in Ameren PY3-PY4 data.
[212] 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.

**MEASURE CODE: RS-HVC-PINS-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

## 5.3.3 Central Air Conditioning

**DESCRIPTION**

This measure characterizes:

a) Time of Sale:

   a. The installation of a new residential sized (<= 65,000 Btu/hr) Central Air Conditioning ducted split system meeting ENERGY STAR efficiency standards presented below. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

   Early Replacement determination will be based on meeting the following conditions:

   - The existing unit is operational when replaced, or
   - The existing unit requires minor repairs (<$190 per ton)[213].
   - All other conditions will be considered Time of Sale.

   The Baseline SEER of the existing Central Air Conditioning unit replaced:

   - If the SEER of the existing unit is known and <=10, the Baseline SEER is the actual SEER value of the unit replaced. If the SEER is >10, the Baseline SEER = 13.
   - If the SEER of the existing unit is unknown, use assumptions in variable list below (SEER_exist).
   - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown[214].

**Deemed Early Replacement Rates For CAC Units in Combined System Replacement (CSR) Projects**

| Replacement Scenario for the CAC Unit | Deemed Early Replacement Rate |
|---|---|
| Early Replacement Rate for a CAC unit when the CAC unit is the Primary unit in a CSR project | 14% |
| Early Replacement Rate for a CAC unit when the CAC unit is the Secondary unit in a CSR project | 40% |

Note it is not appropriate to claim additional ECM fan savings (from 5.3.5 Furnace Blower Motor) due to installing new CAC units with an ECM, since the SEER/EER ratings already account for this electrical load.

Quality Installation:

Additional savings are attributed to the Quality Installation (QI) of the system. QI programs should follow industry standards such as those described in ENERGY STAR Verified HVAC Installation Program (ESVI), ANSI ACCA QI5 and QI9vp. This must include considerations of system design (including sizing, matching, ventilation calculations) and

[213] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[214] Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential funaces. The unit (furnace or CAC unit) that initially caused the customer to contact a trade ally is defined as the “primary unit”. The furnace or CAC unit that was also replaced but did not initially prompt the customer to contact a trade ally is defined as the “secondary unit”. This evaluation used different criteria for early replacement due to the availability of data after the fact; cost of any repairs < $550 and age of unit < 20 years. Report presented to Nicor Gas Company February 27, 2014.

equipment installation (including static pressure, airflow, refrigerant charge) and may also consider distribution.

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

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a ducted split central air conditioning unit meeting at least the minimum ENERGY STAR efficiency level standards; 15 SEER and 12.5 EER.

### DEFINITION OF BASELINE EQUIPMENT

The baseline for the Time of Sale measure is based on the current Federal Standard efficiency level; 13 SEER and an estimate of expected peak rated efficiency of 10.5 EER. It is assumed that 'Quality Installation' did not occur.

The baseline for the early replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and the new baseline as defined above[215] for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years [216].

Remaining life of existing equipment is assumed to be 6 years[217].

### DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below[218]:

| Efficiency Level (SEER) | Incremental Cost |
|---|---|
| 14 | $104 |
| 15 | $108 |
| 16 | $221 |
| 17 | $620 |
| 18 | $620 |

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume defaults below[219].

| Efficiency Level (SEER) | Full Retrofit Cost (including labor) |
|---|---|
| 14 | $952 / ton + $104 |
| 15 | $952 / ton + $108 |
| 16 | $952 / ton + $221 |
| 17 | $952 / ton + $620 |
| 18 | $952 / ton + $620 |

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be

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215 Baseline SEER and EER should be updated when new minimum federal standards become effective.

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

217 Assumed to be one third of effective useful life

218 Based on incremental cost results from Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016.

219 Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator, $2,857. Efficiency cost increment consistent with Cadmus study results.

\$3,140[220]. This cost should be discounted to present value using the nominal societal discount rate.

Quality Installation: The additional design and installation work associated with quality installation has been estimated to cost an additional \$150[221].

#### LOADSHAPE

Loadshape R08 - Residential Cooling

#### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 68%[222]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 46.6%[223]

## Algorithm

#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

Time of sale:

$$\Delta kWH = (FLHcool * Capacity * (1/(SEERbase * (1 - DeratingCool_{Base})) - 1/(SEERee * SEERadj * (1 - DeratingCool_{Eff}))))/1000$$

Early replacement[224]:

ΔkWH for remaining life of existing unit (1st 6 years):

$$=(FLHcool * Capacity * (1/(SEERexist * (1 - DeratingCool_{Base})) - 1/(SEERee * SEERadj * (1 - DeratingCool_{Eff}))))/1000$$

ΔkWH for remaining measure life (next 12 years):

$$= (FLHcool * Capacity * (1/(SEERbase * (1 - DeratingCool_{Base})) - 1/(SEERee * SEERadj * (1 - DeratingCool_{Eff}))))/1000$$

Where:

---

[220] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator, \$2,857, and applying inflation rate of 1.91%. While baselines are likely to shift in the future, there is currently no good indication of what the cost of a new baseline unit will be in 6 years. In the absence of this information, assuming a constant federal baseline cost is within the range of error for this prescriptive measure.

[221] Based on data provided by Mid American in April 2018 summarizing survey results from 11 HVAC suppliers in Iowa.

[222] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[223] 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.

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

FLHcool = Full load cooling hours

= dependent on location and building type[225]:

| Climate Zone (City based upon) | FLHcool (single family) | FLHcool (multifamily) | FLH_cooling (weatherized multifamily) [226] |
|---|---|---|---|
| 1 (Rockford) | 512 | 467 | 299 |
| 2 (Chicago) | 570 | 506 | 324 |
| 3 (Springfield) | 730 | 663 | 425 |
| 4 (Belleville) | 1035 | 940 | 603 |
| 5 (Marion) | 903 | 820 | 526 |
| Weighted Average[227] | 629 | 564 | 362 |

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

Capacity = Size of new equipment in Btu/hr (note 1 ton = 12,000Btu/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[228]. If building type is unknown, assume 31,864Btu/hr[229].

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

= 13[230]

SEERexist = Seasonal Energy Efficiency Ratio f existing unit (kBtu/kWh)

= Use actual SEER rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year to account for degradation over time[231], or if unknown assume 9.3[232].

SEERee = Rated Seasonal Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh)

= Actual, or 15 if unknown.

SEERadj = Adjustment percentage to account for in-situ performance of the unit

---

[225] 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.

[226] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. The multifamily units within this study had undergone significant shell improvements (air sealing and insulation) and therefore this set of assumptions is only appropriate for units that have recently participated in a weatherization or other shell program. Note that the FLHcool where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

[227] Weighted based on number of residential occupied housing units in each zone.

[228] 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.

[229] Unknown is 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.

[230] Based on Minimum Federal Standard.

[231] Justification for degradation factors can be found on page 21 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

[232] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

[233] In situ performance based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC

$= [(0.805 \times \left(\frac{EER_{ee}}{SEER_{ee}}\right) + 0.367]$

DeratingCool$_{Eff}$ = Efficent Central Air Conditioner Cooling derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown[234]

DeratingCool$_{Base}$ = Baseline Central Air Conditioner Cooling derating

= 10%

Time of sale example: a 3 ton unit with SEER rating of 17, EER rating of 12.5 in unknown location without Quality Install:

SEERadj = (0.805 * (12.5/17) + 0.367)
= 0.959

ΔkWH = (629 * 36,000 * (1/(13 * (1-0.1)) – 1 / (17 * 0.959 * (1-0.1)))) / 1000
= 392 kWh

Time of sale example: a 3 ton unit with SEER rating of 17, EER rating of 12.5 in unknown location with Quality Install:

ΔkWH = (629 * 36,000 * (1/(13 * (1-0.1)) – 1 / (17 * 0.959 * (1-0)))) / 1000
= 546 kWh

Early replacement example: a 3 ton unit, with SEER rating of 17, EER rating of 12.5 replaces an existing unit in unknown location with quality installation:

ΔkWH(for first 6 years) = (629 * 36,000 * (1/(9.3 * (1-0.1)) - 1/(17* 0.959 * (1-0))))/1000
= 1,316 kWh

ΔkWH(for next 12 years) = (629 * 36,000 * (1/(13 * (1-0.1)) - 1/(17* 0.959 * (1-0))))/1000
= 546 kWh

Therefore savings adjustment of 41% (546/1316) after 6 years.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

ΔkW = (Capacity * (1/(EERbase * (1 – DeratingCool$_{Base}$)) - 1/(EERee * (1 – DeratingCool$_{Eff}$))))/1000 * CF

Early replacement[235]:

ΔkW for remaining life of existing unit (1st 6 years):

= (Capacity * (1/(EERexist * (1 – DeratingCool$_{Base}$)) - 1/(EERee* (1 – DeratingCool$_{Eff}$))))/1000 * CF

ΔkW for remaining measure life (next 12 years):

HVAC Metering Study Memo FINAL 2_28_2018'.

[234] Based on Cadmus assumption provided in preparation of the 2014 Interstate Power and Light TRM based upon proper refrigerant charge, evaporator airflow, and unit sizing, Appears conservative in comparison to ENERGY STAR statements (see 'Sponsoring an ENERGY STAR Verified HVAC Installation (ESVI) Program'). Note pending ComEd evaluation will provide an update to these assumptions.

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

$= (Capacity * (1/(EERbase * (1 – DeratingCool_{Base})) - 1/(EERee * (1 – DeratingCool_{Eff}))))/1000 * CF$

Where:

EERbase = EER Efficiency of baseline unit

= 10.5 [236]

EERexist = EER Efficiency of existing unit

= Use actual EER rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year to account for degradation over time[237]. If unknown assume 7.5[238]

EERee = EER Efficiency of ENERGY STAR unit

= Actual installed or 12 if unknown

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[239]

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

= 46.6%[240]

Time of sale example: a 3 ton unit with EER rating of 12 with Quality Install:

$\Delta kW_{SSP}$ = (36,000 * (1/(10.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.68

= 0.550 kW

$\Delta kW_{PJM}$ = (36,000 * (1/(10.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 0.377 kW

Early replacement example: a 3 ton unit with EER rating of 12 replaces an existing unit with Quality Install:

$\Delta kW_{SSP}$ (for first 6 years) = (36,000 * (1/(7.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.68

= 1.587 kW

$\Delta kW_{SSP}$ (for next 12 years) = (36,000 * (1/(10.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.68

= 0.550 kW

$\Delta kW_{PJM}$ (for first 6 years) = (36,000 * (1/(7.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 1.087 kW

$\Delta kW_{PJM}$ (for next 12 years) = (36,000 * (1/(10.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 0.377 kW

**NATURAL GAS SAVINGS**

N/A

[236] The federal Standard does not currently include an EER component. The value provided is based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.
[237] Justification for degradation factors can be found on page 21 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[238] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.
[239] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[240] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

**Measure Code: RS-HVC-CAC1-V08-190101**

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

## 5.3.4 Duct Insulation and Sealing

### Description

This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system.

Two methodologies for estimating the savings associate from sealing the ducts are provided. The first preferred method requires the use of a blower door and the second requires careful inspection of the duct work.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p.44 of the Energy Conservatory Blower Door Manual; which can be found on the Energy Conservatory website (As of Oct 2014: http://www.energyconservatory.com/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf)
2. **Evaluation of Distribution Efficiency** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table'; http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf
    a. Percentage of duct work found within the conditioned space
    b. Duct leakage evaluation
    c. Duct insulation evaluation

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient condition is sealed duct work throughout the unconditioned or semi-conditioned space in the home. A non-conditioned space is defined as a space outside of the thermal envelope of the building that is not intentionally heated for occupancy (crawl space, roof attic, etc). A semi-conditioned space is defined as a space within the thermal envelop that is not intentionally heated for occupancy (unfinished basement)[241].

### Definition of Baseline Equipment

The existing baseline condition is leaky duct work within the unconditioned or semi-conditioned space in the home.

### Deemed Lifetime of Efficient Equipment

The assumed lifetime of this measure is 20 years[242].

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years[243]. See section below for detail.

### Deemed Measure Cost

The actual duct sealing measure cost should be used.

### Loadshape

Loadshape R08 - Residential Cooling

[241] Definition matches Regain factor discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012

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

[243] 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.

Loadshape R09 - Residential Electric Space Heat

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

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[244]

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

= 46.6%[245]

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

***Methodology 1: Modified Blower Door Subtraction***

a) Determine Duct Leakage rate before and after performing duct sealing:
Duct Leakage ($CFM50_{DL}$) = ($CFM50_{Whole\ House}$ – $CFM50_{Envelope\ Only}$) * SCF

Where:

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

$CFM50_{Envelope\ Only}$ = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.

SCF = Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.

b) Calculate duct leakage reduction, convert to $CFM25_{DL}$ and factor in Supply and Return Loss Factors
Duct Leakage Reduction ($\Delta CFM25_{DL}$) = (Pre $CFM50_{DL}$ – Post $CFM50_{DL}$) * 0.64 * (SLF + RLF)

Where:

0.64 = Converts CFM50 to CFM25[246]

SLF = Supply Loss Factor

= % leaks sealed located in Supply ducts * 1 [247]

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244 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

245 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.

246 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual).

247 Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks

Default = 0.5[248]

RLF = Return Loss Factor

= % leaks sealed located in Return ducts * 0.5[249]

Default = 0.25[250]

c) Calculate Electric Energy Savings:

$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{Fan}$

$\Delta kWh_{cooling}$ = ((ΔCFM25$_{DL}$/ ((CapacityCool/12,000) * 400)) * FLHcool * CapacityCool * TRFcool) / 1000 / ηCool

$\Delta kWh_{Fan}$ = (ΔTherms * $F_e$ * 29.3)

Where:

ΔCFM25$_{DL}$ = Duct leakage reduction in CFM25

= calculated above

CapacityCool = Capacity of Air Cooling system (Btu/hr)

=Actual

12,000 = Converts Btu/H capacity to tons

400 = Converts capacity in tons to CFM (400CFM / ton)[251]

FLHcool = Full load cooling hours

= Dependent on location as below[252]:

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[253] | 629 | 564 |

are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in “Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements” from Energy Conservatory ‘Minneapolis Duct Blaster Operation Manual’.

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

[249] Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than “average” (e.g. pulling return air from a super heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space) . More information provided in “Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements” from Energy Conservatory ‘Minneapolis Duct Blaster Operation Manual’.

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

[251] This conversion is an industry rule of thumb; e.g. see ‘Why 400 CFM per ton.pdf’.

[252] 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.

[253] Weighted based on number of occupied residential housing units in each zone.

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

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.4 for Semi-Conditioned Spaces[254]

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume the following[255]:

| Age of Equipment | SEER Estimate |
|---|---|
| Before 2006 | 10 |
| After 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

ΔTherms = Therm savings as calculated in Natural Gas Savings

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[256]

29.3 = kWh per therm

[254] Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[255] 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.

[256] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For example, duct sealing in unconditioned space a single family house in Springfield with a 36,000 Btu/H, SEER 11 central air conditioning, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following blower door test results:

Before: $CFM50_{Whole\ House}$ = 4800 CFM50

$CFM50_{Envelope\ Only}$ = 4500 CFM50

House to duct pressure of 45 Pascals. = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4600 CFM50

$CFM50_{Envelope\ Only}$ = 4500 CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29

= 387 CFM

$CFM50_{DL\ after}$ = (4600 – 4500) * 1.39

= 139 CFM

Duct Leakage reduction at CFM25:

$\Delta CFM25_{DL}$ = (387 – 139) * 0.64 * (0.5 + 0.25)

= 119 CFM25

Energy Savings:

$\Delta kWh_{cooling}$ = [((119 / ((36,000/12,000) * 400)) * 730 * 36,000 * 1) / 1000 / 11] + (212 * 0.0314 * 29.3)

= 237 + 195

= 432 kWh

<u>Heating savings for homes with electric heat:</u>

$\Delta kWh_{heating}$ = (($\Delta CFM25_{DL}$ /((OutputCapacityHeat/12,000) * 400)) * FLHheat * OutputCapacityHeat * TRFheat) / ηHeat / 3412

Where:

OutputCapacityHeat = Heating output capacity (Btu/hr) of electric heat

=Actual

FLHheat = Full load heating hours

= Dependent on location as below[257]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[258] | 1,821 |

[257] Heating EFLH based on ENERGY STAR EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.
[258] Weighted based on number of occupied residential housing units in each zone.

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[259]

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use[260]:

| System Type | Age of Equipment | HSPF Estimate | COP Estimate |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 2.00 |
| | After 2006 - 2014 | 7.7 | 2.26 |
| | 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1.00 |

3412 = Converts Btu to kWh

For example, duct sealing in unconditioned space in a 36,000 Btu/H 2.5 COP heat pump heated single family house in Springfield with the blower door results described above:

$\Delta kWh_{heating}$ = ((119 / ((36,000/12,000) * 400)) * 1,754 * 36,000 * 1) / 2.5 / 3412

= 734 kWh

***Methodology 2: Evaluation of Distribution Efficiency***

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

$$\Delta kWh = ((((DE_{after} - DE_{before}) / DE_{after}) * FLHcool * CapacityCool * TRFcool)/1000 / \eta Cool) + (\Delta Therms * F_e * 29.3)$$

Where:

$DE_{after}$ = Distribution Efficiency after duct sealing

$DE_{before}$ = Distribution Efficiency before duct sealing

FLHcool = Full load cooling hours

= Dependent on location as below[261]:

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |

[259] Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

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

[261] 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.

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[262] | 629 | 564 |

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

CapacityCool = Capacity of Air Cooling system (Btu/hr)

=Actual

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.4 for Semi-Conditioned Spaces[263]

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume[264]:

| Age of Equipment | SEER Estimate |
|---|---|
| Before 2006 | 10 |
| After 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

For example, duct sealing in unconditioned space in a single family house in Springfield, with 36,000 Btu/H SEER 11 central air conditioning, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following duct evaluation results:

$DE_{before}$ = 0.85

$DE_{after}$ = 0.92

Energy Savings:

$\Delta kWh_{cooling}$ = ((((0.92 – 0.85)/0.92) * 730 * 36,000 * 1) / 1000 / 11) + (212 * 0.0314 * 29.3)

= 182 + 195

= 377 kWh

<u>Heating savings for homes with electric heat:</u>

$\Delta kWh_{heating}$ = $((DE_{after} - DE_{before})/ DE_{after}))$ * FLHheat * OutputCapacityHeat * TRFheat) / ηHeat / 3412

Where:

[262] Weighted based on number of occupied residential housing units in each zone.

[263] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[264] 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.

OutputCapacityHeat = Heating output capacity (Btu/hr) of the electric heat

=Actual

FLHheat = Full load heating hours

= Dependent on location as below[265]:

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

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[267]

COP = Coefficient of Performance of electric heating system[268]

= Actual. If not available use[269]:

| System Type | Age of Equipment | HSPF Estimate | COP Estimate |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 2.00 |
| | After 2006 - 2014 | 7.7 | 2.26 |
| | 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1.00 |

For example, duct sealing in unconditioned space in a 36,000 Btu/H, 2.5 COP heat pump heated single family house in Springfield with the following duct evaluation results:

$DE_{after}$ = 0.92

$DE_{before}$ = 0.85

Energy Savings:

$\Delta kWh_{heating}$ = ((0.92 – 0.85)/0.92) * 1,754 * 36,000 * 1) / 2.5) / 3412

= 563 kWh

[265] Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.

[266] Weighted based on number of occupied residential housing units in each zone.

[267] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[268] Note that the HSPF of a heat pump is equal to the COP * 3.413.

[269] 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.

### Summer Coincident Peak Demand Savings

$\Delta kW = \Delta kWh_{cooling} / FLHcool * CF$

Where:

FLHcool = Full load cooling hours:

= Dependent on location as below[270]:

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[271] | 629 | 564 |

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

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[272]

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

= 46.6%[273]

### Natural Gas Savings

For homes with Natural Gas Heating:

***Methodology 1: Modified Blower Door Subtraction***

$\Delta Therm = (((\Delta CFM25_{DL} / (InputCapacityHeat * 0.0123)) * FLHheat * InputCapacityHeat * TRFheat * (\eta Equipment / \eta System)) / 100{,}000$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25

InputCapacityHeat = Heating input capacity (Btu/hr)

=Actual

0.0123 = Conversion of Capacity to CFM (0.0123CFM / Btu/hr)[274]

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[270] 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.

[271] Weighted based on number of occupied residential housing units in each zone.

[272] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[273] 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.

[274] Based on Natural Draft Furnaces requiring 100 CFM per 10,000 Btu, Induced Draft Furnaces requiring 130CFM per 10,000Btu and Condensing Furnaces requiring 150 CFM per 10,000 Btu (rule of thumb from 'Practical Standards to Measure HVAC System Performance'). Data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggested that in 2000, 24% of furnaces purchased in Illinois were condensing units. Therefore a weighted average required airflow rate is calculated assuming a 50:50 split of natural v induced draft non-condensing furnaces, as 123 per 10,000Btu or 0.0123/Btu.

FLHheat = Full load heating hours

=Dependent on location as below[275]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[276] | 1,821 |

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[277]

100,000 = Converts Btu to therms

ηEquipment = Heating Equipment Efficiency

= Actual[278]. If not available use 83%[279]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[280]

= Actual. If not available use 70%[281]

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[275] Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.

[276] Weighted based on number of occupied residential housing units in each zone.

[277] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[278] The Equipment Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.
If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

[279] 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) = 0.829

[280] 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 'DistributionEfficiencyTable-Blue Sheet') or by performing duct blaster testing.

[281] Estimated as follows: 0.829 * (1-0.15) = 0.70

For example, duct sealing in unconditioned space in a house in Springfield with an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following blower door test results:

Before: $CFM50_{Whole\ House}$ = 4800 CFM50

$CFM50_{Envelope\ Only}$ = 4500CFM50

House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4600 CFM50

$CFM50_{Envelope\ Only}$ = 4500CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29

= 387 CFM

$CFM50_{DL\ after}$ = (4600 – 4500) * 1.39

= 119 CFM

Duct Leakage reduction at CFM25:

$\Delta CFM25_{DL}$ = (387 – 139) * 0.64 * (0.5 + 0.25)

= 119 CFM25

Energy Savings:

Pre Distribution Efficiency = 1 – (387/4800) = 92%

ηSystem = 80% * 92% = 74%

ΔTherm = ((119/ (105,000 * 0.0123)) * 1,754 * 105,000 * 1 *(0.8/0.74)) / 100,000

= 183 therms

***Methodology 2: Evaluation of Distribution Efficiency***

$$\Delta Therm = ((DE_{after} - DE_{before})/ DE_{after})) * FLHheat * InputCapacityHeat * TRFheat * (\eta Equipment / \eta System)) / 100,000$$

Where:

$DE_{after}$ = Distribution Efficiency after duct sealing

$DE_{before}$ = Distribution Efficiency before duct sealing

Other variables as defined above

For example, duct sealing in unconditioned space in a house in Springfield an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following duct evaluation results:

$DE_{after}$ = 0.92

$DE_{before}$ = 0.85

Energy Savings:

ηSystem = 80% * 85% = 68%

ΔTherm = (((0.92 – 0.85)/0.92) * 1,754 * 105,000 * 1 * (0.8/0.68)) / 100,067

= 165 therm

**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 | Heat Pump (8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace 90% AFUE * 0.85 | 76.5% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years[282].

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-DINS-V07-190101**

**REVIEW DEADLINE: 1/1/2022**

[282] 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.

## 5.3.5 Furnace Blower Motor

### DESCRIPTION

An brushless permanent magnet (BPM) motor (known and referred in this measure as an electronically commutated motor (ECM)) is installed instead of a lower efficiency motor. This measure characterizes the electric savings associated with the fan and the interactive negative therm savings due to a reduction in waste heat of the fan when operating in heating mode. The efficiency ratings of high efficiency ASHP and CAC systems already account for the use of an ECM furnace blower motor, therefore incremental ECM savings are not incurred during heating or cooling for ASHP's or cooling for CAC's if savings are calculated for these systems using their AHRI efficiency ratings.

Savings decrease sharply with static pressure so duct improvements, and clean, low pressure drop filters can maximize savings. Savings occur when the blower is used for heating, cooling as well as when it is used for continuous ventilation, but only if the non-ECM motor would have been used for continuous ventilation too. If the resident runs the ECM blower continuously because it is a more efficient motor and would not run a non-ECM motor that way, savings are near zero and possibly negative. This characterization uses a 2016 Ameren Illinois study of ECM blower motors in Illinois, which accounted for the effects of this behavioral impact.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

A brushless permanent magnet (ECM) blower motor, also known by the trademark ECM, BLDC, and other names.

### DEFINITION OF BASELINE EQUIPMENT

A non-ECM blower motor.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years[283].

### DEEMED MEASURE COST

The capital cost for this measure is assumed to be $97[284].

### LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

### COINCIDENCE FACTOR

ECMs installed in high efficiency CACs and ASHPs do not generate peak demand cooling savings if demand savings are claimed for these systems. However, some savings are realized for fans operating in circulation mode, even during peak demand cooling periods. Circulation mode operation during peak cooling periods would only occur when a system is not operating in cooling mode, with the percent time in circulation mode calculated using the summer system peak and PJM peak coincidence factors. A metering study[285] found 23% of fans operated continuously during

[283] Consistent with assumed life of a BPM/ECM motor, Appendix 8-E of the DOE Technical support documents for federal residential appliance standards.

[284] Adapted from Tables 8.2.3 and 8.2.13 in the DOE Technical support documents for federal residential appliance standards.

[285] See Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study

the summer peak periods therefore ECMs do generate some demand savings during peak periods (when the system is not cooling). ECMs installed with CACs or ASHPs not receiving a rebate improve the cooling efficiency and therefore generate additional peak demand savings (when the system is cooling). Demand savings vary with system size and can be calculated using factors listed in the demand savings calculation table in the next section which incorporate coincidence with peak in their calculation.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWh = Capacity_cooling * kWhSavingsPerTon

Where:

Capacity_cooling = Capacity of cooling system in tons

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

kWhSavingsPerTon = Blower fan kWh savings per ton of cooling[286]

The per-ton energy savings values vary by system installation scenario and location as provided below. Where new *high efficiency* cooling systems are being installed, savings from the blower motor are lower as the efficiency rating of the new cooling system will include this benefit. If a lower efficiency cooling system is installed or an existing one is not replaced, additional savings are claimed due to reduced fan energy during the cooling season. Assumptions are also provided for installation with no or unknown cooling system.

| Region | ASHP Receiving Rebate (Most Common) | Existing or Federal Minimum Efficiency ASHP | CAC Receiving Rebate (Most Common) | Existing or Federal Minimum Efficiency CAC | Furnace, No Cooling System* | Furnace, Cooling System unknown* [287] |
|---|---|---|---|---|---|---|
| Rockford | 114 | 247 | 198 | 229 | 210 | 223 |
| Chicago | 116 | 245 | 195 | 230 | 208 | 222 |
| Springfield | 115 | 249 | 186 | 231 | 203 | 221 |
| Belleville | 121 | 247 | 171 | 235 | 196 | 222 |
| Marion | 123 | 242 | 175 | 231 | 196 | 219 |
| Average | 115 | 247 | 192 | 230 | 206 | 222 |
| *Multiply kWh saved value by 2 tons for furnaces <70 kBTU, by 3 tons for furnaces 70 kBTU – 90 kBTU and by 4 tons for furnaces 90+ kBTU. | | | | | | |

Memo FINAL 2_28_2018'.

[286] Tons of cooling was determined to be the most straightforward multiplier to apply to systems in which the BPM is installed. The basis of the values and for more information see Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[287] Unknown cooling system values are based on a weight of 66% existing CAC and 34% no cooling factors. Based on 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)

For example, an BPM installed with a three ton, 16 SEER CAC receiving a rebate in a home in Marion:

ΔkWh = 3 * 175

= 525 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Capacity_cooling * kWSavingsPerTon

Where:

kWSavingsPerTon = Blower fan kW savings per ton of cooling[288]

The per-ton energy savings values vary by system installation scenario and location as provided below. Where new *high efficiency* cooling systems are being installed, savings from the blower motor are lower as the efficiency rating of the new cooling system will include this benefit. If a lower efficiency cooling system is installed or an existing one is not replaced, additional savings are claimed due to reduced fan energy during the cooling season. Assumptions are also provided for installation with no or unknown cooling system.

| Demand Savings Type | ASHP Receiving Rebate (Most Common) | Existing or Federal Minimum Efficiency ASHP | CAC Receiving Rebate (Most Common) | Existing or Federal Minimum Efficiency CAC | Furnace, No Cooling System* | Furnace, Cooling System unknown* [289] |
|---|---|---|---|---|---|---|
| SSP | 0.006 | 0.085 | 0.006 | 0.085 | 0.013 | 0.065 |
| PJM | 0.01 | 0.064 | 0.01 | 0.064 | 0.009 | 0.048 |

*Multiply kWh saved value by 2 tons for furnaces <70 kBTU, by 3 tons for furnaces 70 kBTU – 90 kBTU and by 4 tons for furnaces 90+ kBTU.

For example, a BPM installed with a three ton, 16 SEER CAC receiving a rebate in a home in Marion:

$\Delta kW_{ssp}$ = 3 * 0.006

= 0.018 kW

$\Delta kW_{pjm}$ = 3 * 0.010

= 0.030 kW

### NATURAL GAS SAVINGS

Δtherms[290] = - HeatingkWhSavings * 0.03412/ AFUE

Where:

[288] Tons of cooling was determined to be the most straightforward multiplier to apply to systems in which the BPM is installed. The basis of the values and for more information see Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[289] Unknown cooling system values are based on a weight of 66% existing CAC and 34% no cooling factors. Based on 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)

[290] The blower fan is in the heating duct so all, or very nearly all, of its waste heat is delivered to the conditioned space. Negative value since this measure will increase the heating load due to reduced waste heat.

HeatingkWhSavings = Heating kWh savings per ton of cooling[291]

Use the location-specific values in the following table to determine heating savings based on the size of the cooling system. If cooling size is unknown, assume 2 tons for furnaces <70 kBTU, 3 tons for furnaces 70 kBTU – 90 kBTU and 4 tons for furnaces 90+ kBTU. If heating size is unknown or if the system does not include cooling, assume a 3-ton system.

| Region | Heating Savings (kWh per ton of cooling) |
|---|---|
| Rockford | 61 |
| Chicago | 59 |
| Springfield | 50 |
| Belleville | 39 |
| Marion | 39 |
| Average | 56 |

0.03412 = Converts kWh to therms

AFUE = Efficiency of the Furnace

= Actual. If unknown assume 95%[292] if in new furnace or 64.4 AFUE% [293] if in existing furnace

For example, an ECM installed with a three ton CAC and 95% AFUE furnace in a home in Marion:

Δtherms = (-39 kWh * 3 tons * 0.03412) / 0.95

Δtherms = - 4.2 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-FBMT-V04-190101**

**REVIEW DEADLINE: 1/1/2022**

[291] Tons of cooling was determined to be the most straightforward multiplier to apply to systems in which the BPM is installed. The basis of the values and for more information see Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See ‘AIC HVAC Metering Study Memo FINAL 2_28_2018’.
[292] Minimum ENERGY STAR efficiency after 2.1.2012.
[293] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

## 5.3.6 Gas High Efficiency Boiler

### Description

High efficiency boilers achieve most gas savings through the utilization of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, some of the flue gasses condense and must be drained.

This measure characterizes:

a) Time of Sale:

   a. The installation of a new high efficiency, gas-fired hot water boiler in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

   Early Replacement determination will be based on meeting the following conditions:

   - The existing unit is operational when replaced, or
   - The existing unit requires minor repairs (<$709)[294].
   - All other conditions will be considered Time of Sale.

   The Baseline AFUE of the existing unit replaced:

   - If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 82%.
   - If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
   - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown[295].

**Deemed Early Replacement Rates For Boilers**

| | Deemed Early Replacement Rate |
|---|---|
| Early Replacement Rate for Boiler participants | 7% |

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

### Definition of Efficient Equipment

To qualify for this measure the installed Boiler must be ENERGY STAR qualified (AFUE rated at or greater than 85% and input capacity less than 300,000 Btu/hr).

[294] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[295] Based upon research from "Home Energy Efficiency Rebate Program GPY2 Evaluation Report" which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. This is used as a reasonable proxy for boiler installations since boiler specific data is not available. Report presented to Nicor Gas Company February 27, 2014.

### DEFINITION OF BASELINE EQUIPMENT

Time of sale: The baseline equipment for this measure is a new, gas-fired, standard-efficiency water boiler. The current Federal Standard minimum is 82% AFUE.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years[296].

Early replacement: Remaining life of existing equipment is assumed to be 8 years[297].

### DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is dependent on tier[298]:

| Measure Type | Installation Cost | Incremental Install Cost |
|---|---|---|
| AFUE 82% | $3543 | n/a |
| AFUE 85% (ENERGY STAR Minimum) | $4268 | $725 |
| AFUE 90% | $4815 | $1,272 |
| AFUE 95% | $5328 | $1,785 |

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $4,045[299]. This cost should be discounted to present value using the nominal discount rate.

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[296] Table 8.3.3 The Technical support documents for federal residential appliance standards.
[297] Assumed to be one third of effective useful life
[298] Based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are.
[299] $3543 inflated using 1.91% rate.

**NATURAL GAS SAVINGS**

Time of Sale:

ΔTherms = (EFLH * CAPInput * (AFUE(eff) / AFUE(base) -1)) / 100000

Early replacement[300]:

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

= (EFLH * CAPInput * (AFUE(eff) / AFUE(exist) -1)) / 100000

ΔTherms for remaining measure life (next 17 years):

= (EFLH * CAPInput * (AFUE(eff) / AFUE(base) -1)) / 100000

Where:

CAPInput = Gas Boiler input capacity (Btuh)

= Actual

EFLH = Equivalent Full Load Hours for gas heating

| Climate Zone (City based upon) | EFLH[301] |
|---|---|
| 1 (Rockford) | 1022 |
| 2 (Chicago) | 976 |
| 3 (Springfield) | 836 |
| 4 (Belleville) | 645 |
| 5 (Marion) | 656 |
| Weighted Average[302] | 928 |

AFUE(exist) = Existing Boiler Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 61.6 AFUE% [303].

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

= 82%

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

= Actual. If unknown, use defaults dependent[304] on tier as listed below:

| Measure Type | AFUE(eff) |
|---|---|
| ENERGY STAR® | 87.5% |
| AFUE 90% | 92.5% |

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

[301] Full load hours for Chicago, are based on findings in 'Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.

[302] Weighted based on number of occupied residential housing units in each zone.

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

[304] Default values per tier selected based upon the average AFUE value for the tier range except for the top tier where the minimum is used due to proximity to the maximum possible.

| Measure Type | AFUE(eff) |
|---|---|
| AFUE 95% | 95% |

Time of Sale:

For example, a 100,000 Btuh, 90%AFUE ENERGY STAR boiler purchased and installed near Springfield

ΔTherms = (836 * 100000 * (0.90/0.82 – 1)) / 100000

= 81.6 Therms

Early Replacement:

For example, an existing function boiler with unknown efficiency is replaced with a 100,000 Btuh, 90%AFUE ENERGY STAR boiler purchased and installed in Springfield.

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

= (836 * 100000 * (0.90/0.616 – 1)) / 100000

= 385.4 Therms

ΔTherms for remaining measure life (next 17 years):

= (836 * 100000 * (0.90/0.82 – 1)) / 100000

= 81.6 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-GHEB-V07-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.3.7 Gas High Efficiency Furnace

**DESCRIPTION**

High efficiency furnace features may include improved heat exchangers and modulating multi-stage burners.

This measure characterizes:

a) Time of sale:

   a. The installation of a new high efficiency, gas-fired condensing furnace in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<$528)[305].
- All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:

- If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
- If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
- If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown[306].

**Deemed Early Replacement Rates For Furnaces**

| Replacement Scenario for the Furnace | Deemed Early Replacement Rate |
|---|---|
| Early Replacement Rate for Furnace-only participants | 7% |
| Early Replacement Rate for a furnace when the furnace is the Primary unit in a Combined System Replacement (CSR) project | 14% |
| Early Replacement Rate for a furnace when the furnace is the Secondary unit in a CSR project | 46% |

Verified Quality Installation

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and BTU measurement to ensure that newly installed equipment is operating according to manufacturers' published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the

[305] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[306] Based upon research from "Home Energy Efficiency Rebate Program GPY2 Evaluation Report" which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential funaces. The unit (furnace or CAC unit) that initially caused the customer to contact a trade ally is defined as the "primary unit". The furnace or CAC unit that was also replaced but did not initially prompt the customer to contact a trade ally is defined as the "secondary unit". This evaluation used different criteria for early replacement due to the availability of data after the fact; cost of any repairs < $550 and age of unit < 20 years. Report presented to Nicor Gas Company February 27, 2014.

equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Install identifies sub-optimal performance and prescribes a solution during furnace installation.

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

#### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a residential sized (input energy less than 225,000 Btu/hr) natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating exceeding the program requirements.

#### Definition of Baseline Equipment

Time of Sale: The current Federal Standard for gas furnaces is an AFUE rating of 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. We estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.

#### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years[307].

For early replacement: Remaining life of existing equipment is assumed to be 6 years[308].

#### Deemed Measure Cost

Time of sale: The incremental installed cost (retail equipment cost plus installation cost) for this measure depends on efficiency as listed below[309]:

| AFUE | Installed Cost | Incremental Installed Cost |
|---|---|---|
| 80% | $2011 | n/a |
| 90% | $2641 | $630 |
| 91% | $2727 | $716 |
| 92% | $2813 | $802 |
| 93% | $3025 | $1014 |
| 94% | $3237 | $1226 |
| 95% | $3449 | $1438 |
| 96% | $3661 | $1650 |

Early Replacement: The full installed cost is provided in the table above. The assumed deferred cost (after 6 years) of replacing existing equipment with a new 90% baseline unit is assumed to be $2903[310]. This cost should be discounted to present value using the nominal discount rate.

Verified Quality Installation: The additional design and installation work associated with verified quality installation

[307] Table 8.3.3 The Technical support documents for federal residential appliance standards.

[308] Assumed to be one third of effective useful life

[309] Based on data from Table E.1.1 of Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are. Note that ECM furnace fan cost (refer to other measure in TRM) has been deducted from the 93%-96% AFUE values to avoid double counting.

[310] $2641 inflated using 1.91% rate.

has been estimated to take 1-2 hours (Tim Hanes, ESI). At $40/hr, VQI adds $60 to the installed cost.

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Electrical energy savings from the more fan-efficient (typically using brushless permanent magnet (BPM) blower motor) should also be claimed, please refer to "Furnace Blower Motor" characterization for details.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

If the blower motor is also used for cooling, coincident peak demand savings should also be claimed, please refer to "Furnace Blower Motor" characterization for savings details.

**NATURAL GAS SAVINGS**

Time of Sale:

$$\Delta Therms = \frac{\frac{EFLH * CAPInput}{(1 - Derating_{eff})} * \left(\frac{AFUE(eff) * (1 - Derating(eff))}{AFUE(base) * (1 - Derating(base))} - 1\right)}{100{,}000}$$

Early replacement[311]:

ΔTherms for remaining life of existing unit (1st 6 years):

$$= \frac{\frac{EFLH * CAPInput}{(1 - Derating_{eff})} * \left(\frac{AFUE(eff) * (1 - Derating(eff))}{AFUE(exist) * (1 - Derating(base))} - 1\right)}{100{,}000}$$

ΔTherms for remaining measure life (next 14 years):

$$= \frac{\frac{EFLH * CAPInput}{(1 - Derating_{eff})} * \left(\frac{AFUE(eff) * (1 - Derating(eff))}{AFUE(base) * (1 - Derating(base))} - 1\right)}{100{,}000}$$

Where:

CAPInput = Gas Furnace input capacity (Btuh)

= Actual

EFLH = Equivalent Full Load Hours for gas heating

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

| Climate Zone (City based upon) | EFLH[312] |
|---|---|
| 1 (Rockford) | 1022 |
| 2 (Chicago) | 976 |
| 3 (Springfield) | 836 |
| 4 (Belleville) | 645 |
| 5 (Marion) | 656 |
| Weighted Average[313] | 928 |

AFUE(exist) = Existing Furnace Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4 AFUE% [314].

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

= Dependent on program type as listed below[315]:

| Program Year | AFUE(base) |
|---|---|
| Time of Sale | 80% |
| Early Replacement [316] | 90% |

AFUE(eff) = Efficent Furnace Annual Fuel Utilization Efficiency Rating

= Actual. If unknown, assume 95%[317]

Derating(base) =Baseline furnace AFUE derating

= 6.4%[318]

Derating(eff) =Efficent furnace AFUE derating

=0% if verified quality installation is performed

=6.4% if verified quality installation is not performed or unknown[319]

312 Full load hours for Chicago, are based on findings in 'Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.

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

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

315 Though the Federal Minimum AFUE is 78%, there were only 50 models listed in the AHRI database at that level. At AFUE 79% the total rises to 308. There are 3,548 active furnace models listed with AFUE ratings between 78 and 80.

316 We estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.

317 Minimum ENERGY STAR efficiency after 2.1.2012.

318 Brand, L., Yee, S., and Baker, J. "Improving Gas Furnace Performance: A Field and Laboratory Study at End of Life." Building Technologies Office. National Renewable Energy Laboratory. 2015 accessed September 6th, 2016.

319 Ibid

Time of Sale:

For example, a 95% AFUE, 80,000Btuh furnace purchased and installed with verified quality installation for an existing home near Rockford:

ΔTherms = ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.8 * (1-0.064))) – 1)) / 100067

= 220 therms

For example, a 95% AFUE, 80,000Btuh furnace purchased and installed without verified quality installation for an existing home near Rockford:

ΔTherms = ((1022 * 80,000)/(1-0.064) * (((0.95 * (1-0.064)) / (0.8 * (1-0.064))) – 1)) / 100067

=164 therms

Early Replacement:

For example, an existing functioning furnace with unknown efficiency is replaced with an 95% AFUE, 80,000Btuh furnace using quality installation in Rockford:

ΔTherms for remaining life of existing unit (1st 6 years):

= ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.644 * (1-0.064))) – 1)) / 100067

= 471 therms

ΔTherms for remaining measure life (next 14 years):

= ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.9 * (1-0.064))) – 1)) / 100067

= 104 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-GHEF-V08-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.3.8 Ground Source Heat Pump

### DESCRIPTION

This measure characterizes the installation of a Ground Source Heat Pump under the following scenarios:

a) New Construction:

   i. The installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new home.
   ii. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

b) Time of Sale:

   i. The planned installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   ii. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.

c) Early Replacement/Retrofit:

   i. The early removal of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   ii. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   iv. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced, or
      - The existing unit requires minor repairs, defined as costing less than[320]:

| Existing System | Maximum repair cost |
|---|---|
| Air Source Heat Pump | $276 per ton |
| Central Air Conditioner | $190 per ton |
| Boiler | $709 |
| Furnace | $528 |
| Ground Source Heat Pump | <$249 per ton |

      - All other conditions will be considered Time of Sale.

   v. The Baseline efficiency of the existing unit replaced:
      - If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the "New Baseline" column below:

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

| Existing System | Maximum efficiency for Actual | New Baseline |
|---|---|---|
| Air Source Heat Pump | 10 SEER | 14 SEER |
| Central Air Conditioner | 10 SEER | 13 SEER |
| Boiler | 75% AFUE | 82% AFUE |
| Furnace | 75% AFUE | 80% AFUE |
| Ground Source Heat Pump | 10 SEER | 13 SEER |

- If the efficiency of the existing unit is unknown, use assumptions in variable list below (SEER, HSPF or AFUE exist).
- If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment must be a Ground Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed below:

ENERGY STAR Requirements (Effective January 1, 2012)

| Product Type | Cooling EER | Heating COP |
|---|---|---|
| Water-to-air | | |
| Closed Loop | 17.1 | 3.6 |
| Open Loop | 21.1 | 4.1 |
| Water-to-Water | | |
| Closed Loop | 16.1 | 3.1 |
| Open Loop | 20.1 | 3.5 |
| DGX | 16 | 3.6 |

**DEFINITION OF BASELINE EQUIPMENT**

For these products, baseline equipment includes Air Conditioning, Space Heating and Water Heating.

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8[321] EER and a Federal Standard electric hot water heater.

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER. If a gas water heater, the Federal Standard baseline is calculated as follows; 0.6483 – (0.0017 * storage capacity in gallons) for tanks<=55 gallons and 0.7897 − (0.0004 × storage capacity in gallons) for greater than 55 gallon storage water heaters.[322]. For a 40-gallon storage water heater this would be 0.58 EF.

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit,

[321] The Federal Standard does not include an EER requirement, so it is approximated with this formula: (-0.02 * SEER2) + (1.12 * SEER) Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

[322] Minimum Federal standard as of 4/16/2015.

meeting the baselines provided below.

| Unit Type | Efficiency Standard |
|---|---|
| ASHP | 14 SEER, 11.8 EER, 8.2 HSPF |
| Gas Furnace | 80% AFUE |
| Gas Boiler | 82% AFUE |
| Central AC | 13 SEER, 11 EER |

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change).

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years[323].

For early replacement, the remaining life of existing equipment is assumed to be 8 years[324].

### DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump should be used (default of $3957 per ton[325]), minus the assumed installation cost of the baseline equipment ($1381 per ton for ASHP[326] or $2011 for a new baseline 80% AFUE furnace or $3543 for a new 82% AFUE boiler[327] and $952 per ton[328] for new baseline Central AC replacement).

Early Replacement: The full installation cost of the Ground Source Heat Pump should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and 1,047 per ton for new baseline Central AC replacement[329]. This future cost should be discounted to present value using the nominal societal discount rate.

### LOADSHAPE

| | |
|---|---|
| Loadshape R10 - Residential Electric Heating and Cooling | (if replacing gas heat and central AC)[330] |
| Loadshape R09 - Residential Electric Space Heat | (if replacing electric heat with no cooling) |
| Loadshape R10 - Residential Electric Heating and Cooling | (if replacing ASHP) |

Note for purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape R09 - Residential Electric Space Heat and Loadshape R08 – Residential Cooling respectively) can be applied.

---

[323] System life of indoor components as per DOE estimate (see 'Geothermal Heat Pumps Department of Energy'). The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.

[324] Assumed to be one third of effective useful life

[325] Based on data provided in 'Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives'.

[326] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation.

[327] Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor.

[328] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator.

[329] All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.

[330] The baseline for calculating electric savings is an Air Source Heat Pump.

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%%[331]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[332]

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

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

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]

$= [FLHcool * Capacity\_cooling * (1/SEER_{base} – 1/EER_{PL})/1000] + [Elecheat * FLHheat * Capacity\_heating * (1/HSPF_{base} – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * \%DHWDisplaced * ((1/EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]$

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

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

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

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

$= [FLHcool * Capacity\_cooling * (1/SEER_{base} – 1/EER_{PL})/1000] + [FLHheat * Capacity\_heating * (1/HSPF_{ASHP} – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * \%DHWDisplaced * ((1/EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]$

Early replacement (non-fuel switch only)[333]:

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

= [Cooling savings] + [Heating savings] + [DHW savings]

$= [FLHcool * Capacity\_cooling * (1/SEERexist – 1/EER_{PL})/1000] + [ElecHeat * FLHheat * Capacity\_heating * (1/HSPFexist – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * \%DHWDisplaced * ((1/ EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]$

---

[331] 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)'.
[332] 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.
[333] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

ΔkWH for remaining measure life (next 17 years):

= [FLHcool * Capacity_cooling * (1/SEERbase – 1/$EER_{PL}$)/1000] + [ElecHeat * FLHheat * Capacity_heating * (1/HSPFbase – (1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

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

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

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

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

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

= [FLHcool * Capacity_cooling * (1/SEERexist – 1/$EER_{PL}$)/1000] + [FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

ΔkWh for remaining measure life (next 17 years):

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

= [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/$EER_{PL}$)/1000] + [FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

Where:

FLHcool = Full load cooling hours

Dependent on location as below[334]:

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily | FLH_cooling (weatherized multifamily) [335] |
|---|---|---|---|
| 1 (Rockford) | 512 | 467 | 299 |
| 2 (Chicago) | 570 | 506 | 324 |
| 3 (Springfield) | 730 | 663 | 425 |
| 4 (Belleville) | 1,035 | 940 | 603 |
| 5 (Marion) | 903 | 820 | 526 |
| Weighted Average[336] | 629 | 564 | 362 |

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

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

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

[334] 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.

[335] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. The multifamily units within this study had undergone significant shell improvements (air sealing and insulation) and therefore this set of assumptions is only appropriate for units that have recently participated in a weatherization or other shell program. Note that the FLHcool where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

[336] Weighted based on number of occupied residential housing units in each zone.

SEERbase = SEER Efficiency of new replacement baseline unit

| Existing Cooling System | SEERbase |
|---|---|
| Air Source Heat Pump | 14[337] |
| Central AC | 13[338] |
| No central cooling | 13[339] |

SEERexist = SEER Efficiency of existing cooling unit

= Use actual SEER rating where it is possible to measure or reasonably estimate, if unknown assume default provided below:

| Existing Cooling System | SEER_exist |
|---|---|
| Air Source Heat Pump | 9.3[340] |
| Ground Source Heat Pump | 10[341] |
| Central AC | 9.3[342] |
| No central cooling | 13 [343] |

$SEER_{ASHP}$ = SEER Efficiency of new baseline Air Source Heat Pump unit (for fuel switch)

= 14 [344]

$EER_{PL}$ = Part Load EER Efficiency of efficient GSHP unit[345]

= Actual installed

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

FLHheat = Full load heating hours

Dependent on location as below[346]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |

337 Minimum Federal Standard as of 1/1/2015

338 Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

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

340 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

341 Estimate of existing GSHP efficiency is based upon assumptions used by ICF in Missouri. It is recommended that this value be evaluated and adjusted for a future version.

342 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

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

344 Minimum Federal Standard as of 1/1/2015.

345 As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.

346 Heating EFLH based on ENERGY STAR EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 5 (Marion) | 1,288 |
| Weighted Average[347] | 1,821 |

Capacity_heating = Heating Capacity of Ground Source Heat Pump (Btu/hr)

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

$HSPF_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

| Existing Heating System | HSPF_base |
|---|---|
| Air Source Heat Pump | 8.2 |
| Electric Resistance | 3.41[348] |

HSPF_exist =Heating System Performance Factor of existing heating system (kBtu/kWh)

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If unknown assume default:

| Existing Heating System | HSPF_exist |
|---|---|
| Air Source Heat Pump | 5.54[349] |
| Ground Source Heat Pump | 8.2[350] |
| Electric Resistance | 3.41 |

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

=8.2 [351]

$COP_{PL}$ = Part Load Coefficient of Performance of efficient unit[352]

= Actual Installed

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

ElecDHW = 1 if existing DHW is electrically heated

= 0 if existing DHW is not electrically heated

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

= Actual if known

= If unknown and if desuperheater installed assume 44%[353]

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

348 Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.

349 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

350 Estimate of existing GSHP efficiency is assumed equivalent to a new baseline ASHP. It is recommended that this value be evaluated and adjusted for a future version.

351 Minimum Federal Standard as of 1/1/2015

352 As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.

353 Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 * 2/3 = 44%). Based on input from Doug Dougherty, Geothermal Exchange Organization.

= 0% if no desuperheater installed

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

= Actual. If unknown or for new construction assume federal standard[354]:

For <=55 gallons: 0.96 – (0.0003 * rated volume in gallons)

For >55 gallons: 2.057 – (0.00113 * rated volume in gallons)

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[355]

= 17.6

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[356] |
| Multifamily - Deemed | 2.1[357] |
| Custom | Actual Occupancy or Number of Bedrooms[358] |

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municiplal system

= 54°F[359]

1.0 = Heat Capacity of water (1 Btu/lb*°F)

3412 = Conversion from Btu to kWh

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354 Minimum Federal Standard as of 4/1/2015;.

355 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

356 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

357 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

358 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

359 US DOE Building America Program. Building America Analysis Spreadsheet.

Illustrative Examples

New Construction using ASHP baseline:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed with a 50 gallon electric water heater in single family house in Springfield:

ΔkWh = [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/$EER_{PL}$)/1000] + [FLHheat * Capacity_heating * (1/HSPFbase – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

ΔkWh = [730 * 36,000 * (1/14 – 1/19) / 1000] + [1754* 36,000 * (1/8.2 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 494 + 3494 + 1328

= 5316 kWh

Early Replacement – non-fuel switch (see example after Natural gas section for Fuel switch):

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed in single family house in Springfield with a 50 gallon electric water heater replacing an existing working Air Source Heat Pump with unknown efficiency ratings:

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

= [730 * 36,000 * (1/9.3 - 1/19) / 1000] + [1754 * 36,000 * (1/5.54 - 1/(4.4 * 3.412)) / 1000] + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 1443 + 7191 + 1328

= 9,963 kWh

ΔkWH for remaining measure life (next 17 years):

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

= 494 + 3494 + 1328

= 5316 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

New Construction and Time of Sale:

ΔkW = (Capacity_cooling * (1/EERbase - 1/$EER_{FL}$))/1000 * CF

Early replacement:

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

= (Capacity_cooling * (1/EERexist - 1/$EER_{FL}$))/1000 * CF

ΔkW for remaining measure life (next 17 years):

= (Capacity_cooling * (1/EERbase - 1/$EER_{FL}$))/1000 * CF

Where:

EERbase = EER Efficiency of new replacement unit

| Existing Cooling System | EER_base |
|---|---|
| Air Source Heat Pump | 11.8[360] |

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

| Existing Cooling System | EER_base |
|---|---|
| Central AC | 11 [361] |
| No central cooling | 11[362] |

EERexist = Energy Efficiency Ratio of existing cooling unit (kBtu/hr / kW)

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

$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$ [363]

If SEER rating unavailable use:

| Existing Cooling System | EER_exist |
|---|---|
| Air Source Heat Pump | 7.5[364] |
| Ground Source Heat Pump | 11[366] |
| Central AC | 7.5[367] |
| No central cooling | 11 [368] |

$EER_{FL}$ = Full Load EER Efficiency of ENERGY STAR GSHP unit [369]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 72%%[370]

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

= 46.6%[371]

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361 Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

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

363 From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

364 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

366 Assumed equal to ASHP.

367 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

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

369 As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP.

370 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)'.

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

New Construction or Time of Sale:

For example, a 3 ton unit with Full Load EER rating of 19:

$\Delta kW_{SSP}$ = (36,000 * (1/11.8 – 1/19))/1000 * 0.72

= 0.83 kW

$\Delta kW_{PJM}$ = (36,000 * (1/11 – 1/19))/1000 * 0.466

= 0.54 kW

Early Replacement:

For example, a 3 ton Full Load 19 EER replaces an existing working Air Source Heat Pump with unknown efficiency ratings in Marion:

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

= (36,000 * (1/7.5 – 1/19))/1000 * 0.72

= 2.09 kW

$\Delta kW_{SSP}$ for remaining measure life (next 17 years):

= (36,000 * (1/11.8 – 1/19))/1000 * 0.72

= 0.83 kW

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

= (36,000 * (1/7.5 – 1/19))/1000 * 0.466

= 1.35 kW

$\Delta kW_{PJM}$ for remaining measure life (next 17 years):

= (36,000 * (1/11.8 – 1/19))/1000 * 0.466

= 0.54 kW

**NATURAL GAS SAVINGS**

New Construction and Time of Sale with baseline gas heat and/or hot water:

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

ΔTherms = [Heating Savings] + [DHW Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat * Capacity_heating * 1/($COP_{PL}$ * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

If measure is supported by electric utility only, ΔTherms = 0

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

ΔTherms = [Heating Savings] + [DHW Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

Early replacement for homes with existing gas heat and/or hot water:

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

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

= [Heating Savings] + [DHW Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/($COP_{PL}$ * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/($COP_{PL}$ * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

If measure is supported by electric utility only, ΔTherms = 0

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

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

ΔTherms = [Heating Savings] + [DHW Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

Gas_Heating_Load

= Estimate of annual household heating load [372] for gas furnace heated single-family homes. If location is unknown, assume the average below.

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[373].

[372] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE )

[373] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.

| Climate Zone (City based upon) | Gas_Heating_Load if Furnace (therms) [374] | Gas_Heating_Load if Boiler (therms) [375] |
|---|---|---|
| 1 (Rockford) | 873 | 1275 |
| 2 (Chicago) | 834 | 1218 |
| 3 (Springfield) | 714 | 1043 |
| 4 (Belleville) | 551 | 805 |
| 5 (Marion) | 561 | 819 |
| Average | 793 | 1158 |

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating

= 80% if furnace and 82% if boiler.

AFUEexist = Existing Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4% if furnace and 61.6% [376] if boiler.

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

= 90%[377] if furnace and 82% if boiler.

kWhtoTherm = Converts source kWh to Therms

= $H_{grid}$ / 100000

$H_{grid}$ = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[378]. Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include

[374] Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[375] Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

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

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

[378] Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

- Non-Baseload RFC West: 10,539 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,968 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,962 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 9,996 Btu/kWh * (1 + Line Losses)

any line losses.

3.412 = Converts COP to HSPF

$EF_{GAS\ EXIST}$ = Energy Factor (efficiency) of existing gas water heater

= Actual. If unknown assume federal standard[379]:

For <=55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

For > 55 gallons 0.7897 − (0.0004 * storage capacity in gallons)

= If tank size unknown assume 40 gallons and EF_Baseline of 0.58

All other variables provided above

Illustrative Examples *[for illustrative purposes a Heat Rate of 10,000 Btu/kWh is used]*

New construction using gas furnace and central AC baseline, *supported by Gas utility only*:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater is installed in place of a natural gas furnace and 3 ton Central AC unit:

ΔkWH = 0

ΔTherms = [Heating Savings] + [DHW Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat * Capacity_heating * 1/($COP_{PL}$ * 3.412)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,067)]

= [(1-0) * ((714/0.80) – (10000/100000 * 1754 * 36,000 * 1/(4.4 * 3.412))/1000)] + [(1 – 0) * (0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,067)]

= 472 + 74

= 546 therms

Early Replacement fuel switch, *supported by gas and electric utility*:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings:

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

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

= [(FLHcool * Capacity_cooling * (1/SEERexist – (1/$EER_{PL}$)/1000] + [(FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – (1/$COP_{PL}$ * 3.412)))/1000] + [ElecDHW * %DHWDisplaced * (((1/ $EF_{ELEC}$) * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

= [(730* 36,000 * (1/8.6 - 1/19)) / 1000] + [(1754 * 36,000 * (1/8.2 - 1/(4.4 * 3.412))) / 1000] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 1673 + 3494 + 0

= 5167 kWh

Continued on next page.

[379] Minimum Federal Standard as of 4/1/2015.

Illustrative Example continued

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings] + [DHW savings]

= [(FLHcool * Capacity_cooling * (1/$SEER_{base}$ – (1/$EER_{PL}$)/1000] + [(FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – (1/$COP_{PL}$ * 3.412)))/1000] + [ElecDHW * %DHWDisplaced * (((1/ $EF_{ELEC}$) * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) /3412)]

= [(730 * 36,000 * (1/13 – 1/19)) / 1000] + [1754 * 36,000 * (1/8.2 – 1/ (4.4 *3.412)) / 1000] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) *1)/3412)]

= 638 + 3494 + 0

= 4132 kWh

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

= [Heating Savings] + [DHW Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

= [(1-0) * ((714/0.644) – (10000/100000 * 1754 * 36,000 * 1/8.2)/1000)] + [(1 – 0) * (0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]

= 339 + 74

= 412 therms

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

= [(1-0) * ((714/0.9) – (10000/100000 * 1754 * 36,000 * 1/8.2)/1000)] + [(1 – 0) * (0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]

= 23 + 74

= 97 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING**

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch GSHP projects per Section 16-111.5B, changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[380]] + [DHW Savings if gas]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

ΔkWh = - [GSHP heating consumption] + [Cooling savings[381]] + [DHW savings if electric]

= - [(FLHheat * Capacity_heating * (1/$COP_{PL}$ * 3.412))/1000] + [(FLHcool * Capacity_cooling * (1/SEERbase - 1/$EER_{PL}$))/1000] + [ElecDHW * %DHWDisplaced * ((1/$EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 9-25)]:

ΔTherms = [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,067)]

= [(1-0) * (714/0.644)] + [((1 – 0) * 0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,0067)]

= 1109 + 74

= 1183 therms

ΔkWh = - [(FLHheat * Capacity_heating * (1/$COP_{PL}$ * 3.412))/1000] + [(FLHcool * Capacity_cooling * (1/SEERexist - 1/$EER_{PL}$))/1000] + [ElecDHW * %DHWDisplaced * (((1/$EF_{ELEC}$) * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

= - [(1754 * 36,000 * (1/(4.4 * 3.412)))/ 1000] + [(730 * 36,000 * (1/9.3 - 1/19))/ 1000)] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= -4206 + 1443 + 0

= -2763 kWh

**MEASURE CODE: RS-HVC-GSHP-V08-190101**

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

380 Note AFUEbase in the algorithm should be replaced with AFUEexist for early replacement measures.

381 Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures.

## 5.3.9 High Efficiency Bathroom Exhaust Fan

### Description

This market opportunity measure is split in to the purchase of a new bathroom fan for typical usage, and to meet the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes fan capacities between 10 and 200 CFM rated at a sound level of less than 2.0 sones at 0.1 inches of water column static pressure, or 50 CFM if used for continuous ventilation. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

New efficient ENERGY STAR or ENERGY STAR Most Efficient exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2 - 2016[382]. ENERGY STAR specifications (effective October 1 2015) and 2018 Most Efficient specifications are provided below:

| Efficiency Level | Fan Capacity | Minimum Efficacy Level (CFM/Watts) | Maximum Allowable Sound Level (sones) |
|---|---|---|---|
| ENERGY STAR | 10 – 89 CFM | 2.8 | 2.0 |
| | 90 – 200 CFM | 3.5 | |
| ENERGY STAR Most Efficient | All | 10 | |

### Definition of Baseline Equipment

New standard efficiency exhaust-only ventilation fan.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 19 years[383].

### Deemed Measure Cost

Incremental cost per installed fan is $43.50 for quiet, efficient fans[384].

### Loadshape

Loadshape R11 - Residential Ventilation

### Coincidence Factor

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

---

[382] Bi-level controls may be used by efficient fans larger than 50 CFM

[383] Conservative estimate based upon GDS Associates Measure Life Report “Residential and C&I Lighting and HVAC measures” 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.

[384] VEIC analysis using cost data collected from wholesale vendor.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh = (CFM * (1/\eta_{,BASELINE} - 1/\eta_{EFFICIENT})/1000) * Hours$

Where:

CFM = Nominal Capacity of the exhaust fan

= Actual or use defaults provided below

= Assume 50CFM for continuous ventilation[385]

$\eta_{BASELINE}$ = Average efficacy for baseline fan (CFM/watts)

= See table below

$\eta_{EFFCIENT}$ = Average efficacy for efficient fan (CFM/watts)

= Actual or use defaults provided below

Hours = assumed annual run hours,

= 1089 for standard usage[386]

= 8766 for continuous ventilation.

Defaults provided below[387]:

| | | | | | ENERGY STAR | | ENERGY STAR Most Efficient | |
|---|---|---|---|---|---|---|---|---|
| Application | Min CFM | Max CFM | Average CFM | Base CFM/Watts | CFM/Watts | ΔkWh Savings | CFM/Watts | ΔkWh Savings |
| Standard usage | 10 | 89 | 70.6 | 1.7 | 4.9 | 28.9 | 12.0 | 38.2 |
| | 90 | 200 | 116.1 | 2.6 | 5.6 | 25.3 | 13.9 | 38.7 |
| | Unknown | | 92.4 | 2.2 | 5.3 | 27.4 | 12.9 | 38.6 |
| Continuous usage | N/A | | 50 | 1.7 | 5.1 | 170.7 | 11.2 | 216.9 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = (CFM * (1/\eta_{BASELINE} - 1/_{EFFICIENT})/1000) * CF$

Where:

CF = Summer Peak Coincidence Factor

= 0.135 for standard usage

= 1.0 for continuous operation

Other variables as defined above

[385] 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.

[386] Assumed to be consistent with Residential Indoor Lighting hours of use.

[387] Based on review of Bathroom Exhaust Fan product available on CEC Appliance Database, accessed 6/18/2018. See 'CEC Bath Fan.xls' for more information.

| Application | Min CFM | Max CFM | Average CFM | ENERGY STAR ΔkW Savings | ENERGY STAR Most Efficient ΔkW Savings |
|---|---|---|---|---|---|
| Standard usage | 10 | 89 | 70.6 | 0.0036 | 0.0047 |
| | 90 | 200 | 116.1 | 0.0031 | 0.0048 |
| | Unknown | | 92.4 | 0.0034 | 0.0048 |
| Continuous usage | N/A | | 50 | 0.0195 | 0.0247 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-BAFA-V02-190101**

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

## 5.3.10 HVAC Tune Up (Central Air Conditioning or Air Source Heat Pump)

### DESCRIPTION

This measure involves the measurement of refrigerant charge levels and airflow over the central air conditioning or heat pump unit coil, correction of any problems found and post-treatment re-measurement. Measurements must be performed with standard industry tools and the results tracked by the efficiency program.

Savings from this measure are developed using a reputable Wisconsin study. It is recommended that future evaluation be conducted in Illinois to generate a more locally appropriate characterization.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

N/A

### DEFINITION OF BASELINE EQUIPMENT

This measure assumes that the existing unit being maintained is either a residential central air conditioning unit or an air source heat pump that has not been serviced for at least 3 years.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 2 years[388].

### DEEMED MEASURE COST

If the implementation mechanism involves delivering and paying for the tune up service, the actual cost should be used. If however the customer is provided a rebate and the program relies on private contractors performing the work, the measure cost should be assumed to be $175[389].

### LOADSHAPE

Loadshape R08 - Residential Cooling

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[390]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[391]

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388 Based on VEIC professional judgment.

389 Based on personal communication with HVAC efficiency program consultant Buck Taylor or Roltay Inc., 6/21/10, who estimated the cost of tune up at $125 to $225, depending on the market and the implementation details.

390 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

391 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)'.

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

= 46.6%[392]

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$\Delta kWh_{Central\ AC}$ = (FLHcool * Capacity_cooling* (1/$SEER_{CAC}$))/1000 * MFe

$\Delta kWh_{Air\ Source\ Heat\ Pump}$ = ((FLHcool * Capacity_cooling * (1/$SEER_{ASHP}$))/1000 * MFe) + (FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$))/1000 * MFe)

Where:

FLHcool = Full load cooling hours

Dependent on location as below:[393]

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[394] | 629 | 564 |

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

Capacity_cooling = Cooling cpacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)

= Actual

$SEER_{CAC}$ = SEER Efficiency of existing central air conditioning unit receiving maintenence

= Actual. If unknown assume 10 SEER [395]

MFe = Maintenance energy savings factor

= 0.05[396]

$SEER_{ASHP}$ = SEER Efficiency of existing air source heat pump unit receiving maintenence

= Actual. If unknown assume 10 SEER [397]

FLHheat = Full load heating hours

[392] 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.
[393] 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.
[394] Weighted based on number of occupied residential housing units in each zone.
[395] Use actual SEER rating where it is possible to measure or reasonably estimate. Unknown default of 10 SEER is a VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006.
[396] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."
[397] Use actual SEER rating where it is possible to measure or reasonably estimate. Unknown default of 10 SEER is a VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006.

Dependent on location:[398]

| Climate Zone (City based upon) | FLHheat |
|---|---|
| 1 (Rockford) | 2208 |
| 2 (Chicago) | 2064 |
| 3 (Springfield) | 1967 |
| 4 (Belleville) | 1420 |
| 5 (Marion) | 1445 |
| Weighted Average[399] | 1821 |

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

= Actual

$HSPF_{ASHP}$ = Heating Season Performance Factor of existing air source heat pump unit receiving maintenence

= Actual. If unknown assume 6.8 HSPF [400]

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

$\Delta kWh_{CAC}$ = (730 * 36,000 * (1/10))/1000 * 0.05

= 131 kWh

For example, maintenance of a 3-ton, SEER 10, HSPF 6.8 air source heat pump unit in a single family house in Springfield:

$\Delta kWh_{ASHP}$ = ((730 * 36,000 * (1/10))/1000 * 0.05) + (1967 * 36,000 * (1/6.8))/1000 * 0.05)

= 652 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = Capacity_cooling * (1/EER)/1000 * MFd * CF

Where:

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

= Calculate using Actual SEER

= $- 0.02*SEER^2 + 1.12*SEER$ [401]

[398] Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the ENERGY STARCalculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider ENERGY STARestimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from Illinois Commerce Commission) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the ENERGY STAR data (1994 hours) to scale down the ENERGY STAR estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[399] Weighted based on number of occupied residential housing units in each zone.

[400] Use actual HSPF rating where it is possible to measure or reasonably estimate. Unknown default of 6.8 HSPF is a VEIC estimate based on minimum Federal Standard between 1992 and 2006.

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

MFd = Maintenance demand savings factor

= 0.02 [402]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[403]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[404]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C and Heat Pumps (average during peak period)

= 46.6%[405]

For example, maintenance of 3-ton, SEER 10 (equals EER 9.2) CAC unit:

$\Delta kW_{SSP}$ = 36,000 * 1/(9.2)/1000 * 0.02 * 0.68

= 0.0532 kW

$\Delta kW_{PJM}$ = 36,000 * 1/(9.2)/1000 * 0.02 * 0.466

= 0.0365 kW

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Conservatively not included.

**MEASURE CODE: RS-HVC-TUNE-V04-190101**

**REVIEW DEADLINE: 1/1/2021**

[402] Based on June 2010 personal conversation with Scott Pigg, author of Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research" suggesting the average WI unit system draw of 2.8kW under peak conditions, and average peak savings of 50W.
[403] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[404] 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)'.
[405] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

## 5.3.11 Programmable Thermostats

### DESCRIPTION

This measure characterizes the household energy savings from the installation of a new or reprogramming of an existing Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Because a literature review was not conclusive in providing a defensible source of prescriptive cooling savings from programmable thermostats, cooling savings from programmable thermostats are assumed to be zero for this version of the measure. It is not appropriate to assume a similar pattern of savings from setting a thermostat down during the heating season and up during the cooling season. Note that the EPA's EnergyStar program is developing a new specification for this project category, and if/when evaluation results demonstrate consistent cooling savings, subsequent versions of this measure will revisit this assumption[406]. Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple programmable thermostats per home does not accrue additional savings.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control, with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention. This category of equipment is broad and rapidly advancing in regards to the capability, and usability of the controls and their sophistication in setpoint adjustment and information display, but for the purposes of this characterization, eligibility is perhaps most simply defined by what it isn't: a manual only temperature control.

For the thermostat reprogramming measure, the auditor consults with the homeowner to determine an appropriate set back schedule, reprograms the thermostat and educates the homeowner on its appropriate use.

### DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature setpoint.

For the purpose of thermostat reprogramming, an existing programmable thermostat that an auditor determines is being used in override mode or otherwise effectively being operated like a manual thermostat.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a programmable thermostat is assumed to be 8 years[407]. For reprogramming, this is reduced further to give a measure life of 2 years.

### DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown (e.g. through a retail program) the capital cost for the new installation measure is assumed to be $30[408]. The cost for reprogramming is assumed to be $10 to account for the auditor's time to reprogram and educate the homeowner.

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[406] The ENERGY STAR program discontinued its support for this measure category effective 12/31/09, and is presently developing a new specification for 'Residential Climate Controls'.

[407] 8 years is based upon ASHRAE Applications (2003), Section 36, Table 3 estimate of 16 years for the equipment life, reduced by 50% to account for persistence issues.

[408] Market prices vary significantly in this category, generally increasing with thermostat capability and sophistication. The basic functions required by this measure's eligibility criteria are available on units readily available in the market for the listed price.

**LOADSHAPE**

Loadshape R09 - Residential Electric Space Heat

**COINCIDENCE FACTOR**

N/A due to no savings attributable to cooling during the summer peak period.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWh[409] = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + (ΔTherms * $F_e$ * 29.3)

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

| Heating fuel | %ElectricHeat |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 6.5%[410] |

Elec_Heating_ Consumption

= Estimate of annual household heating consumption for electrically heated homes[411]. If location and heating type is unknown, assume 15,683 kWh[412]

| 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) | 20,777 | 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 |

[409] Note the second part of the algorithm relates to furnace fan savings if the heating system is Natural Gas.

[410] Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat (consistent with Potential Study results from the state). Average value of 13% electric space heating from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[411] 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.

[412] 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.

Heating_Reduction = Assumed percentage reduction in total household heating energy consumption due to programmable thermostat

= 6.2%[413]

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

| Household Type | HF |
|---|---|
| Single-Family | 100% |
| Mobile home | 83%[414] |
| Multifamily | 65%[415] |
| Unknown | 89%[416] |
| Actual | Custom[417] |

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

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and programmed effectively

| Program Delivery | Eff_ISR |
|---|---|
| Direct Install | 100% |
| Other, or unknown | 56%[418] |

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[419]

29.3 = kWh per therm

[413] The savings from programmable thermostats are highly susceptible to many factors best addressed, so far for this category, by a study that controlled for the most significant issues with a very large sample size. To the extent that the treatment group is representative of the program participants for IL, this value is suitable. Higher and lower values would be justified based upon clear dissimilarities due to program and product attributes. Future evaluation work should assess program specific impacts associated with penetration rates, baseline levels, persistence, and other factors which this value represents.

[414] 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.

[415] Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% factor is applied to MF homes based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes

[416] Unknown is 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.

[417] Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

[418] "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness," GDS Associates, Marietta, GA. 2002GDS

[419] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For example, a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield:

ΔkWH = 1 * 17,794 * 0.062 * 100% * 100% + (0 * 0.0314 * 29.3)

= 1,103 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A due to no savings from cooling during the summer peak period.

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

Where:

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

| Heating fuel | %FossilHeat |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 93.5%[420] |

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below[421].

| 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 |

For example, a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

ΔTherms = 1.0 * 1005 * 0.062 * 100% * 100%

= 62.3 therms

[420] Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat. Data from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[421] Values are based on adjusting the average household heating load (834 therms) for Chicago based on 'Table E-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1, Research Report: Furnace Metering Study', divided by standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24*0.92) + (0.76*0.8) = 0.83) to give 1005 therms. This Chicago value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-PROG-V05-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.3.12 Ductless Heat Pumps

### DESCRIPTION

This measure is designed to calculate electric savings for the installation of a ductless mini-split heat pump (DMSHP). DMSHPs save energy in heating mode because they provide heat more efficiently than electric resistance heat and central ASHP systems. Additionally, DMSHPs use less fan energy to move heat and don't incur heat loss through a duct distribution system.

For cooling, the proposed savings calculations are aligned with those of typical replacement systems. DMSHPs save energy in cooling mode because they provide cooling capacity more efficiently than other types of unitary cooling equipment. A DMSHP installed in a home with a central ASHP system will save energy by offsetting some of the cooling energy of the ASHP. In order for this measure to apply, the control strategy for the heat pump is assumed to be chosen to maximize savings per installer recommendation.[422]

This measure characterizes the following scenarios:

d) New Construction:
   a. The installation of a new DMSHP meeting efficiency standards required by the program in a new home.
   b. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

e) Time of Sale:
   a. The planned installation of a new DMSHP meeting efficiency standards required by the program to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   b. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.

f) Early Replacement/Retrofit:
   a. The early removal or displacement of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new DMSHP.
   b. Note the baseline in this case is the existing equipment being replaced/displaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   c. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced/displaced, or
      - The existing unit requires minor repairs, defined as costing less than[423]:

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

[422] The whole purpose of installing ductless heat pumps is to conserve energy, so the installer can be assumed to be capable of recommending an appropriate controls strategy. For most applications, the heating setpoint for the ductless heat pump should be at least 2F higher than any remaining existing system and the cooling setpoint for the ductless heat pump should be at least 2F cooler than the existing system (this should apply to all periods of a programmable schedule, if applicable). This helps ensure that the ductless heat pump will be used to meet as much of the load as possible before the existing system operates to meet the remaining load. Ideally, the new ductless heat pump controls should be set to the current comfort settings, while the existing system setpoints should be adjusted down (heating) and up (cooling) to capture savings.

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

| Existing System | Maximum repair cost |
|---|---|
| Boiler | $709 |
| Furnace | $528 |
| Ground Source Heat Pump | <$249 per ton |

- All other conditions will be considered Time of Sale.

d. The Baseline efficiency of the existing unit replaced:
  - If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the "New Baseline" column below:

| Existing System | Maximum efficiency for Actual | New Baseline[424] |
|---|---|---|
| Air Source Heat Pump | 10 SEER | 14 SEER |
| Central Air Conditioner | 10 SEER | 13 SEER |
| Boiler | 75% AFUE | 82% AFUE |
| Furnace | 75% AFUE | 80% AFUE |
| Ground Source Heat Pump | 10 SEER | 13 SEER |

  - If the efficiency of the existing unit is unknown, use assumptions in variable list below (SEER, HSPF or AFUE exist).
  - If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

This measure was developed to be applicable to the following program types: RF, TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, the new equipment must be a high-efficiency, variable-capacity (typically "inverter-driven" DC motor) ductless heat pump system that exceeds the program minimum efficiency requirements.

### Definition of Baseline Equipment

For these products, baseline equipment includes Air Conditioning and Space Heating:

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8[425] EER.

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER.

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit, meeting the baselines provided below.

| Unit Type | Efficiency Standard |
|---|---|
| ASHP | 14 SEER, 11.8 EER, 8.2 HSPF |
| Gas Furnace | 80% AFUE |

[424] Based on relevant Federal Standards.

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

| Unit Type | Efficiency Standard |
|---|---|
| Gas Boiler | 82% AFUE |
| Central AC | 13 SEER, 11 EER |

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating and cooling equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change). Note that in order to claim cooling savings, there must be an existing air conditioning system.

For multifamily buildings, each residence must have existing individual heating equipment. Multifamily residences with central heating do not qualify for this characterization.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years[426].

For early replacement, the remaining life of existing equipment is assumed to be 6 years[427].

### Deemed Measure Cost

New Construction and Time of Sale: The actual installed cost of the DMSHP should be used (defaults are provided below), minus the assumed installation cost of the baseline equipment ($1,381 per ton for ASHP[428] or $2,011 for a new baseline 80% AFUE furnace or $3,543 for a new 82% AFUE boiler[429] and $952 per ton[430] for new baseline Central AC replacement).

Default full cost of the DMSHP is provided below. Note, for smaller units a minimum cost of $2,000 should be applied[431]:

| Unit Size | Full Install Cost ($/ton)[432] |
|---|---|
| 9-9.9 | $1,443 |
| 10-10.9 | $1,605 |
| 11-12.9 | $1,715 |
| 13+ | $2,041 |

The incremental cost of the DSMHP compared to a baseline minimum efficiency DSMHP is provided in the table below[433].

[426] Based on 2016 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[427] Assumed to be one third of effective useful life
[428] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation.
[429] Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are.
[430] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator
[431] The cost per ton table provides reasonable estimates for installation costs of DMSHP, which can vary significantly due to requirements of the home. It is estimated that all units, even those 1 ton or less will be at least $2000 to install.
[432] Full costs based upon full install cost of an ASHP plus incremental costs provided in Memo from Opinion Dynamics Evaluation Team, Ductless Mini-Split Heat Pumps: Incremental Cost Analysis, April 27, 2017.
[433] Memo from Opinion Dynamics Evaluation Team, Ductless Mini-Split Heat Pumps: Incremental Cost Analysis, April 27, 2017

| Efficiency (HSPF) | Incremental Cost ($/ton) over an HSPF 8.0 DHP |
|---|---|
| 9-9.9 | $62 |
| 10-10.9 | $224 |
| 11-12.9 | $334 |
| 13+ | $660 |

Early Replacement/retrofit (replacing existing equipment): The full installation cost of the DMSHP should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and $1,047 per ton for new baseline Central AC replacement[434]. This future cost should be discounted to present value using the nominal societal discount rate.

Where the DMSHP is a supplemental HVAC system, the full installation cost of the DMSHP should be used (default provided above) without a deferred replacement cost.

**LOADSHAPE**

Loadshape R10 - Residential Electric Heating and Cooling (if replacing gas heat and central AC)435

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

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

Note for purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape R09 - Residential Electric Space Heat and Loadshape R08 – Residential Cooling respectively) can be applied.

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in four different ways below. The first two relate to the use of DMSHP to supplement existing cooling or provide limited zonal cooling, the second two relate to use of the DMSHP to provide whole house cooling. In each pair, the first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on metering data for 40 DMSHPs in Ameren Illinois service territory[436].

For supplemental or limited zonal cooling:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)

= 43.1%%[437]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

= 28.0%[438]

For whole house cooling:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

[434] All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.
[435] The baseline for calculating electric savings is an Air Source Heat Pump.
[436] All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015
[437] 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)'.
[438] 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.

= 72%%[439]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[440]

## Algorithms

### Calculation of Savings

### Electric Energy Savings

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

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Base} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

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

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

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

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

Early replacement (non-fuel switch only)[441]:

ΔkWH for remaining life of existing unit (1st 6 years):

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Exist} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Exist} - 1/SEER_{ee})) / 1000]$

ΔkWH for remaining measure life (next 12 years):

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Base} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

Early replacement - fuel switch only :

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

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

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439 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

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

ΔkWh for remaining life of existing unit (1st 6 years):

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Exist} - 1/SEER_{ee})) / 1000]$

ΔkWh for remaining measure life (next 12 years):

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

$Capacity_{heat}$ = Heating capacity of the ductless heat pump unit in Btu/hr

= Actual

$EFLH_{heat}$ = Equivalent Full Load Hours for heating. Depends on location. See table below

| Climate Zone (City based upon) | $EFLH_{heat}$[442] |
|---|---|
| 1 (Rockford) | 1,520 |
| 2 (Chicago) | 1,421 |
| 3 (Springfield) | 1,347 |
| 4 (Belleville) | 977 |
| 5 (Marion) | 994 |
| Weighted Average | 1,406 |

$HSPF_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

| Existing Heating System | HSPF_base |
|---|---|
| Air Source Heat Pump | 8.2 |
| Electric Resistance | 3.41[443] |

$HSPF_{exist}$ = HSPF rating of existing equipment (kbtu/kwh)

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If unknown assume default:

| Existing Equipment Type | $HSPF_{exist}$ |
|---|---|
| Electric resistance heating | 3.412[444] |
| Air Source Heat Pump | 5.54[445] |

[442] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. FLH values are based on metering of Multifamily units that were used as the primary heating source to the whole home, and in buildings that had received weatherization improvements. A DMSHP installed in a single-family home may be used more sporadically, especially if the DMSHP serves only a room, and buildings that have not been weatherized may require longer hours. Additional evaluation is recommended to refine the EFLH assumptions for the general population.
[443] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
[444] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
[445] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering

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

=8.2 [446]

$HSPF_{ee}$ = HSPF rating of new equipment (kbtu/kwh)

= Actual installed

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr[447].

= Actual installed

SEERbase = SEER Efficiency of new replacement baseline unit

| Existing Cooling System | SEERbase |
|---|---|
| Air Source Heat Pump | 14[448] |
| Central AC | 13[449] |
| No central cooling | 13[450] |

$SEER_{ee}$ = SEER rating of new equipment (kbtu/kwh)

= Actual installed[451]

$SEER_{exist}$ = SEER rating of existing equipment (kbtu/kwh)

= Use actual value. If unknown, see table below

| Existing Cooling System | SEER_exist |
|---|---|
| Air Source Heat Pump | 9.3 |
| Central AC | |
| Room AC | 8.0[453] |
| No existing cooling[454] | Make '1/SEER_exist' = 0 |

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. Depends on location. See table below[455].

Study Memo FINAL 2_28_2018'.

446 Minimum Federal Standard as of 1/1/2015

447 1 Ton = 12 kBtu/hr

448 Minimum Federal Standard as of 1/1/2015

449 Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

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

451 Note that if only an EER rating is available, use the following conversion equation; EER_base = (-0.02 * SEER_base$^2$) + (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.

452 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

453 Estimated by converting the EER assumption using the conversion equation; EER_base = (-0.02 * SEER_base$^2$) + (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.

454 If there is no existing cooling in place but the incentive encourages installation of a new DMSHP with cooling, the added cooling load should be subtracted from any heating benefit.

455 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. FLH values are based on metering of Multifamily units, and in buildings that had received weatherization improvements. Additional evaluation is recommended to refine the EFLH assumptions for the general population.

| Climate Zone (City based upon) | $EFLH_{cool}$ |
|---|---|
| 1 (Rockford) | 323 |
| 2 (Chicago) | 308 |
| 3 (Springfield) | 468 |
| 4 (Belleville) | 629 |
| 5 (Marion) | 549 |
| Weighted Average[456] | 364 |

For example, installing a 1.5-ton (heating and cooling capacity) ductless heat pump unit rated at 8 HSPF and 14 SEER in a single-family home in Chicago to displace electric baseboard heat and replace a window air conditioner of unknown efficiency, savings are:

$\Delta kWh_{heat}$ = (18000 * 1421 * (1/3.412 – 1/8))/1000 = 4,299 kWh

$\Delta kWh_{cool}$ = (18000 * 308 *(1/8.0 – 1/14)) /1000 = 297 kWh

ΔkWh = 4,299 + 297 = 4,596 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

New Construction and Time of Sale:

$\Delta kW = (Capacity_{cool} * (1/EER_{base} - 1/EER_{ee})) / 1000) * CF$

Early replacement:

ΔkW for remaining life of existing unit (1st 6 years):

$\Delta kW = (Capacity_{cool} * (1/EER_{exist} - 1/EER_{ee})) / 1000) * CF$

ΔkW for remaining measure life (next 12 years):

$\Delta kW = (Capacity_{cool} * (1/EER_{base} - 1/EER_{ee})) / 1000) * CF$

Where:

EERbase = EER Efficiency of new replacement unit

| Existing Cooling System | EER_base |
|---|---|
| Air Source Heat Pump | 11.8[457] |
| Central AC | 11 [458] |
| No central cooling | 11[459] |

$EER_{exist}$ = 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:

$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$ [460]

[456] Weighted based on number of residential occupied housing units in each zone.
[457] The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.
[458] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
[459] Assumes that the decision to replace existing systems includes desire to add cooling.
[460] From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations.

If SEER rating unavailable use:

| Existing Cooling System | EER_exist |
|---|---|
| Air Source Heat Pump | 7.5[461] |
| Central AC | 7.5 |
| Room AC | 7.7[462] |
| No existing cooling[463] | Make '1/EER_exist' = 0 |

EER_ee = Energy Efficiency Ratio of new ductless Air Source Heat Pump (kBtu/hr / kW)

= Actual, If not provided convert SEER to EER using this formula: [464]

= $(-0.02 * SEER^2) + (1.12 * SEER)$

For supplemental or limited zonal cooling:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)

= 43.1%[465]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

= 28.0%[466]

For whole house cooling:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%[467]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[468]

**NATURAL GAS SAVINGS**

New Construction and Time of Sale with baseline gas heat:

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

ΔTherms = [Heating Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * $Capacity_{heat}$ *

Masters Thesis, University of Colorado at Boulder.

461 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

462 Same EER as Window AC recycling. Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

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

464 Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

465 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)'.

466 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.

467 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)'.

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

$EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

If measure is supported by electric utility only, ΔTherms = 0

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

ΔTherms = [Heating Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

Early replacement for homes with existing gas heat:

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

ΔTherms for remaining life of existing unit (1st 6 years):

= [Heating Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

ΔTherms for remaining measure life (next 12 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

If measure is supported by electric utility only, ΔTherms = 0

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

ΔTherms for remaining life of existing unit (1st 6 years):

ΔTherms = [Heating Savings]

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

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

ΔTherms for remaining measure life (next 12 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

Gas_Heating_Load

= Estimate of annual household heating load [469] for gas furnace heated single-family homes. If location is unknown, assume the average below.

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[470].

[469] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE )

[470] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment

| Climate Zone (City based upon) | Gas_Heating_Load if Furnace (therms) [471] | Gas_Heating_Load if Boiler (therms) [472] |
|---|---|---|
| 1 (Rockford) | 873 | 1275 |
| 2 (Chicago) | 834 | 1218 |
| 3 (Springfield) | 714 | 1043 |
| 4 (Belleville) | 551 | 805 |
| 5 (Marion) | 561 | 819 |
| Average | 793 | 1158 |

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating

= 80% if furnace and 82% if boiler.

AFUEexist = Existing Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4% if furnace and 61.6% [473] if boiler.

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

= 90%[474] if furnace and 82% if boiler.

kWhtoTherm = Converts source kWh to Therms

= $H_{grid}$ / 100000

$H_{grid}$ = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[475]. Also include any line losses.

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selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.

[471] Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[472] Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

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

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

[475] Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

- Non-Baseload RFC West: 10,539 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,968 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,962 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 9,996 Btu/kWh * (1 + Line Losses)

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

All other variables provided above

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING**

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch DMSHP projects per Section 16-111.5B, changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[476]]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase)]

ΔkWh = - [DMSHP heating consumption] + [Cooling savings[477]]

= - [($Capacity_{heat}$ * $EFLH_{heat}$ * 1/HSPFee)/1000] + [($Capacity_{cool}$* $EFLH_{cool}$ * (1/$SEER_{Base}$- 1/$SEER_{ee}$)) / 1000]

**MEASURE CODE: RS-HVC-DHP-V06-190101**

**REVIEW DEADLINE: 1/1/2021**

[476] Note AFUEbase in the algorithm should be replaced with AFUEexist for early replacement measures.

[477] Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures.

## 5.3.13 Residential Furnace Tune-Up

**DESCRIPTION**

This measure is for a natural gas Residential furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

Two savings algorithms are provided for tune-up programs: through the HVAC SAVE program and for other tune-up programs, the difference being how relative efficiencies are measured.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure an approved technician must complete the tune-up requirements[478] listed below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer's recommendations
- Where applicable Lubricate motor and inspect and replace fan belt if required
- Inspect for gas leaks
- Clean burner per manufacturer's recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer's recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring and controls for proper connections and performance
- Check air filter and clean or replace per manufacturer's
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Check thermostat operation is per manufacturer's recommendations(if adjustments made, refer to 'Residential Programmable Thermostat' measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

Verified Quality Maintenance:

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and BTU measurement to ensure that existing equipment is operating according to manufacturers' published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Maintenance identifies sub-optimal performance and prescribes a solution during furnace tune ups.

The HVAC SAVE program has its own certifications and requirements. In addition to the maintenance described above, the following are key activities that are provided through an HVAC SAVE Verified Quality Maintenance visit[479]:

- Measure pressure drops at return, filter, coil and supply.
- Determine equipment air flow using OEM blower data or measuring.
- Measure temperature rise across heat exchanger.

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[478] American Standard Maintenance for Indoor Units (see 'HVAC Maintenance American Standard')

[479] As provided in ANSI approved ACCA 4 specification for Quality Maintenance

- Determine on-rate for a furnace by clocking the gas meter.
- Record outdoor temperature & elevation, and complete test-in.
- Clean evaporator coil to OEM pressure drop specification.
- Clean/replace/modify air filter to OEM pressure drop specification.
- Reset air flow based on up design parameter and updated pressure conditions.
- Adjust/modify gas pressure and venting to OEM specifications.
- Complete final test-out, compare before and after

#### Definition of Baseline Equipment

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

HVAC SAVE tune-ups are a one-time measure and cannot be performed more than once on the same piece of equipment.

#### Deemed Lifetime of Efficient Equipment

The measure life for the clean and check tune up is 2 years.[480]

An HVAC SAVE tune-up lasts the remaining life of the equipment because they come from adjustments to fans and ducts that remain effective through normal operation of the equipment. Assume 10 years. This measure cannot be performed more than once on the same piece of equipment. However subsequent clean and check tune-ups can be performed.

#### Deemed Measure Cost

The incremental cost for this measure should be the actual cost of tune up.

#### Deemed O&M Cost Adjustments

There are no expected O&M savings associated with this measure.

#### Loadshape

Loadshape R09 - Residential Electric Space Heat

#### Coincidence Factor

N/A

## Algorithms

#### Calculation of Energy Savings

#### Electric Energy Savings

$$\Delta kWh = \Delta Therms * F_e * 29.3$$

Where:

ΔTherms = as calculated below

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[481]

[480] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.

[481] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a

29.3 = kWh per therm

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

1. Verified Quality Maintenance:

The HVAC SAVE protocol results in a number of outputs including the measured output capacity of the unit (btuh), and the adjusted input capacity (btuh) by recording the gas meter.

The following algorithm utilizes these outputs to adjust the EFLH of the post tune-up condition to calculate a site specific savings estimate. There are two limits imposed to using these outputs directly:

1. The post efficiency (i.e. measured output/adjusted input) must not exceed the rated efficiency of the unit. Where the test results indicates an efficiency greater than the rated efficiency, the measured output should be adjusted to equal the value at the rated efficiency,
2. A limit of 15% savings of pre tune-up consumption is applied. Where outputs indicate savings higher than 15%, the program should claim savings at 15%, unless a higher level of independent review is able to justify the higher level of savings.

$$\Delta Therms = ConsumptionPre - ConsumptionPost$$

$$\Delta Therms = \frac{\left((CAPInput_{Pre} * EFLH) - \left(CAPInput_{Post} * \ EFLH * \left(\frac{CAPOutput_{Pre}}{CAPOutput_{Post}}\right)\right)\right)}{100{,}000}$$

Note, if a program prefers, a deemed savings percentage can be applied and this is provided as an alternative below:

$$\Delta Therms = \ (CAPInput_{Pre} * EFLH \ * \ \left(\frac{1}{AFUE \ * \ (1 \ - \ Derating_{Pre})} - \frac{1}{AFUE \ * \ (1 \ - \ Derating_{Post})}\right)$$

Where:

$CAPInput_{Pre}$ = Gas Furnace input capacity pre tune-up (Btuh)

= Measured input capacity from HVAC SAVE

$CAPInput_{Post}$ = Gas Furnace input capacity post tune-up (Btuh)

= Measured input capacity from HVAC SAVE

EFLH = Equivalent Full Load Hours for heating

| Climate Zone (City based upon) | EFLH[482] |
|---|---|
| 1 (Rockford) | 1022 |
| 2 (Chicago) | 976 |

calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

482 Full load hours for Chicago, are based on findings in 'Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.

| Climate Zone (City based upon) | EFLH[482] |
|---|---|
| 3 (Springfield) | 836 |
| 4 (Belleville) | 645 |
| 5 (Marion) | 656 |
| Weighted Average[483] | 928 |

$CAPOutput_{Pre}$ = Measured Output Capacity before HVAC SAVE tune-up (btuh)

$CATOutput_{Post}$ = Measured Output Capacity after HVAC SAVE tune-up (btuh)

AFUE = Furnace Annual Fuel Utilization Efficiency Rating

= Actual

$Derating_{pre}$ = Furnace AFUE Derating before HVAC SAVE tune-up

= 6.4%[484]

$Derating_{post}$ = Furnace AFUE Derating after HVAC SAVE tune-up

= 0%

2. Other Tune-Up Programs:

$$\Delta Therms = (CAPInput_{Pre} * EFLH * (1/ Effbefore – 1/ (Effbefore + Ei)))$$

Where:

Effbefore = Efficiency of the furnace before the tune-up

= Actual

*Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.*

EI = Efficiency Improvement of the furnace tune-up measure

= Actual

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-FTUN-V04-190101**

**REVIEW DEADLINE: 1/1/2021**

[483] Weighted based on number of occupied residential housing units in each zone.
[484] Based on findings from Building America, US Department of Energy, Brand, Yee and Baker "Improving Gas Furnace Performance: A Field and Laboratory Study at End of Life", February 2015.

## 5.3.14 Boiler Reset Controls

### DESCRIPTION

This measure relates to improving system efficiency by adding controls to residential heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. The water can be run a little cooler during fall and spring, and a little hotter during the coldest parts of the winter. A boiler reset control has two temperature sensors - one outside the house and one in the boiler water. As the outdoor temperature goes up and down, the control adjusts the water temperature setting to the lowest setting that is meeting the house heating demand. There are also limits in the controls to keep a boiler from operating outside of its safe performance range.[485]

This measure was developed to be applicable to the following program types: RF.

### DEFINITION OF EFFICIENT EQUIPMENT

Natural gas single family residential customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse fashion with outdoor air temperature. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer's recommended minimum return temperature. This boiler reset measure is limited to existing condensing boilers serving a single family residence. Boiler reset controls for non-condensing boilers in single family residences should be implemented as a custom measure, and the cost-effectiveness should be confirmed.

### DEFINITION OF BASELINE EQUIPMENT

Existing condensing boiler in a single family residential setting without boiler reset controls.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 20 years[486]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 13 years[487]. See section below for detail.

### DEEMED MEASURE COST

The cost of this measure is $612[488]

### LOADSHAPE

NA

### COINCIDENCE FACTOR

N/A

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[485] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors, See 'Boiler Reset Control – NaturalGasEfficiency.org'.
[486] CLEAResult references the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.
[487] 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.
[488] Nexant. Questar DSM Market Characterization Report. August 9, 2006.

**Algorithm**

### Calculation of Energy Savings

### Electric Energy Savings

N/A

### Summer Coincident Peak Demand Savings

NA

### Natural Gas Savings

ΔTherms = Gas_Boiler_Load * (1/AFUE) * Savings Factor

Where:

Gas_Boiler_Load[489]

= Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below[490].

= or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[491].

| Climate Zone (City based upon) | Gas_Boiler Load (therms) |
|---|---|
| 1 (Rockford) | 1275 |
| 2 (Chicago) | 1218 |
| 3 (Springfield) | 1043 |
| 4 (Belleville) | 805 |
| 5 (Marion) | 819 |
| Average | 1158 |

AFUE = Existing Condensing Boiler Annual Fuel Utilization Efficiency Rating

= Actual.

SF = Savings Factor, 5%[492]

[489] Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Heating load is used to describe the household heating need, which is equal to (gas heating consumption * AFUE )

[490] Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[491] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8$^{th}$ Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations should be completed by contractors during the selection process and may be readily available for program data purposes.

[492] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. See 'Boiler Reset Control – NaturalGasEfficiency.org'.

**EXAMPLE**

For example, boiler reset controls on a 92.5 AFUE boiler at a household in Rockford, IL

ΔTherms = 1275 * (1/0.925) * 0.05

= 69 Therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating 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 |
|---|---|---|
| ηHeat | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 13 years[493].

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: RS-HVC-BREC-V02-190101

## REVIEW DEADLINE: 1/1/2021

[493] 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.

## 5.3.15 ENERGY STAR Ceiling Fan

### DESCRIPTION

A ceiling fan/light unit meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard. ENERGY STAR qualified ceiling fan/light combination units are over 60% more efficient than conventional fan/light units, and use improved motors and blade designs.

Due to the savings from this measure being derived from more efficient ventilation and more efficient lighting, and the loadshape and measure life for each component being very different, the savings are split in to the component parts and should be claimed together. Lighting savings should be estimated utilizing the 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as an ENERGY STAR certified ceiling fan with integral CFL bulbs.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a standard fan with efficient incandescent or halogen light bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012 followed by restrictions on 75W in 2013 and 60W and 40W in 2014, due to the Energy Independence and Security Act of 2007 (EISA). Finally, a provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) for the lighting portion of the savings should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The fan savings measure life is assumed to be 10 years.[2]

The lighting savings measure life is assumed to be 3 years for lighting savings for units installed in 2018, and then for every subsequent year should be reduced by one year[494] (see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure).

### DEEMED MEASURE COST

Incremental cost of unit is $46.[495]

### LOADSHAPE

R06 - Residential Indoor Lighting

R11 - Residential Ventilation

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494 Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

495 ENERGY STAR Ceiling Fan Savings Calculator.

### COINCIDENCE FACTOR

The summer peak coincidence factor for the ventilation savings is assumed to be 30%.[496]

For lighting savings, see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{Light}$

$\Delta kWh_{fan}$ = [Days * FanHours * ((%$Low_{base}$ * $WattsLow_{base}$) + (%$Med_{base}$ * $WattsMed_{base}$) + (%$High_{base}$ * $WattsHigh_{base}$))/1000 ] - [Days * FanHours * ((%$Low_{ES}$ * $WattsLow_{ES}$) + (%$Med_{ES}$ * $WattsMed_{ES}$) + (%$High_{ES}$ * $WattsHigh_{ES}$))/1000]

$\Delta kWh_{light}$ = see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

Where[497]:

Days = Days used per year

= Actual. If unknown use 365.25 days/year

FanHours = Daily Fan "On Hours"

= Actual. If unknown use 3 hours

%$Low_{base}$ = Percent of time spent at Low speed of baseline

= 40%

$WattsLow_{base}$ = Fan wattage at Low speed of baseline

= Actual. If unknown use 15 watts

%$Med_{base}$ = Percent of time spent at Medium speed of baseline

= 40%

$WattsMed_{base}$ = Fan wattage at Medium speed of baseline

= Actual. If unknown use 34 watts

%$High_{base}$ = Percent of time spent at High speed of baseline

= 20%

$WattsHigh_{base}$ = Fan wattage at High speed of baseline

= Actual. If unknown use 67 watts

%LowES = Percent of time spent at Low speed of ENERGY STAR

= 40%

$WattsLow_{ES}$ = Fan wattage at Low speed of ENERGY STAR

= Actual. If unknown use 6 watts

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[496] Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[497] All fan default assumptions are based upon assumptions provided in the ENERGY STAR Ceiling Fan Savings Calculator.

$\%Med_{ES}$ = Percent of time spent at Medium speed of ENERGY STAR

= 40%

$WattsMed_{ES}$ = Fan wattage at Medium speed of ENERGY STAR

= Actual. If unknown use 23 watts

$\%High_{ES}$ = Percent of time spent at High speed of ENERGY STAR

= 20%

$WattsHigh_{ES}$ = Fan wattage at High speed of ENERGY STAR

= Actual. If unknown use 56 watts

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

| | Low Speed | Medium Speed | High Speed |
|---|---|---|---|
| Percent of Time at Given Speed | 40% | 40% | 20% |
| Conventional Unit Wattage | 15 | 34 | 67 |
| ENERGY STAR Unit Wattage | 6 | 23 | 56 |
| ΔW | 9 | 11 | 11 |

If the lighting WattsBase and WattsEE is unknown, assume the following

WattsBase = 3 x 43 = 129 W

WattsEE = 1 x 42 = 42 W

**Example**

For example, a ceiling fan with three 43W bulb light fixtures, replaced with an ES ceiling fan with one 42W bulb light fixture, the savings are:

$\Delta kWh_{fan}$ = [365.25*3*((0.4*15)+(0.4*34)+(0.2*67))/1000] – [365.25*3*((0.4*6)+(0.4*23)+(0.2*56))/1000]

= 36.2 – 25.0 = 11.2 kWh

$\Delta kWh_{light}$ =((129 – 42)/1000) *759 * 1.06

= 70.0 kWh

ΔkWh = 11.2 + 70

=81.2 kWh

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

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kW_{Fan} + \Delta kW_{light}$

$\Delta kW_{Fan} = ((WattsHigh_{base} - WattsHigh_{ES})/1000) * CF_{fan}$

$\Delta kW_{Light}$ = see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

Where:

$CF_{fan}$ = Summer Peak coincidence factor for ventilation savings

= 30%[498]

[498] Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report

$CF_{light}$ = Summer Peak coincidence factor for lighting savings

= 7.1%[499]

**Example**

For example a ceiling fan with three 43W bulb light fixtures, replaced with an ES ceiling fan with one 42W bulb light fixture, the savings are:

$\Delta kW_{fan}$ = ((67-56)/1000) * 0.3

=0.0033 kW

$\Delta kW_{light}$ =((129 – 42)/1000) * 1.11 * 0.071

= 0.0068 kW

$\Delta kW$ = 0.0033 + 0.0068

= 0.010 kW

Using the default assumptions provided above, the deemed savings is 0.010kW.

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

See 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure for bulb replacement costs.

**MEASURE CODE: RS-HVC-CFAN-V02-180101**

**REVIEW DEADLINE: 1/1/2022**

Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

499 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

## 5.3.16 Advanced Thermostats

### DESCRIPTION

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating and cooling consumption through a configurable schedule of temperature setpoints (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[500] 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.[501] Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple advanced thermostats per home does not accrue additional savings.

Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[502] 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,[503] or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program

[500] 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.

[501] 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'.

[502] 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.

[503] 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

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[504].

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life for advanced thermostats is assumed to be 11 years[505].

**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[506], or other program types actual costs are still preferable[507] but if unknown then the average incremental cost for the new installation measure is assumed to be $125[508].

**LOADSHAPE**

$\Delta kWh$ → Loadshape R10 - Residential Electric Heating and Cooling
$\Delta kWh_{heating}$ → Loadshape R09 - Residential Electric Space Heat
$\Delta kWh_{cooling}$ → Loadshape R08 - Residential Cooling

**COINCIDENCE FACTOR**

In the absence of conclusive results from empirical studies on peak savings, the TAC agreed to a temporary assumption of 50% of the cooling coincidence factor, acknowledging that while the savings from the advanced Thermostat will track with the cooling load, the impact during peak periods may be lower. This is an assumption that could use future evaluation to improve these estimates.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 34%[509]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[510]

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[504] Based on Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013.

[505] 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.

[506] 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.

[507] Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.

[508] 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.

[509] 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).

[510] Assumes 50% of the cooling coincidence factor (based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.)

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh$[511] = $\Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating}$ = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + ($\Delta$Therms * $F_e$ * 29.3)

$\Delta kWh_{cool}$ = %AC * ((FLH * Capacity * 1/SEER)/1000) * Cooling_Reduction * Eff_ISR

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

| Heating fuel | %ElectricHeat |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 3%[512] |

Elec_Heating_Consumption

= Estimate of annual household heating consumption for electrically heated homes[513]. If location and heating type is unknown, assume 15,683 kWh[514]

| 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

[511] 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.

[512] 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"

[513] 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.

[514] 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.

| Existing Thermostat Type | Heating_Reduction[515] |
|---|---|
| Manual | 8.8% |
| Programmable | 5.6% |
| Unknown (Blended) | 7.0% |

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

| Household Type | HF |
|---|---|
| Single-Family | 100% |
| Mobile home | 83%[516] |
| Multifamily | 65%[517] |
| Actual | Custom[518] |
| Unknown | 96.5%[519] |

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

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication. Note that retrospective adjustments should be made during evaluation verification activities through the use of a realization rate if the program design does not ensure that each advanced thermostat is actually installed and/or if the evaluation determines that the advanced thermostat is not actually installed in the Program Administrator's service territory.

| Program Delivery | Eff_ISR |
|---|---|
| Direct Install | 100% |
| Other | 100%[520] |

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[521]

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515 These values represent adjusted baseline savings values (8.8% for manual, and 5.6% for programmable thermostats) as presented in Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'). These values are used as the basis for the weighted average savings value when the type of existing thermostat is not known. Using 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. The 7.0% savings value is equal to the sum of proportional savings for manual (including non-programmed programmable)and programmable thermostats: 8.8% * 0.43 + 5.6% * 0.57. Further evaluation and regular review of this key assumption is encouraged.

516 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.

517 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

518 Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

519 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 the PY8 split communicated by Navigant as part of the current evaluation.

520 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.

521 $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a

29.3 = kWh per therm

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

| Thermostat control of air conditioning? | %AC[522] |
|---|---|
| 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 location and cooling type are unknown, assume the weighted average.

| Climate zone (city based upon) | FLH (single family) [523] | FLH (general multifamily) [524] | FLH_cooling (weatherized multi family) [525] |
|---|---|---|---|
| 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[526] | 629 | 564 | 293 |

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

Capacity = Size of AC unit[527]. (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

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% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

522 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 ;

523 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.

524 Ibid.

525 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015

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

527 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.

Btu/hr for mobile homes[528]. If building type is unknown, assume 31,864Btu/hr[529].

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[530] |
|---|---|
| Air Source Heat Pump | 9.3 |
| 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[531]:

= 8%[532]

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

= 1 * 10,464 * 5.6% * 100% * 100% + (0 * 0.0314 * 29.3) + 100% * ((730 * 33,600 * (1/9.3))/1000) * 6.3% * 100%

= 586kWh + 166 kWh

= 752 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = %AC * (Cooling_Reduction * Btu/hr * (1/EER)/1000) * EFF_ISR * CF

Where:

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

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

528 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.

529 Unknown is 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.

530 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

531 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.

532 Note: In an effort to resolve potential disputes, without the need for litigation regarding the cooling reduction value in the IL-TRM for advanced thermostats, Stakeholders have reached through negotiation a separate stipulation that retains the 8% cooling reduction value in the 2019 IL-TRM Version 7.0, pending completion of a statewide advanced thermostat evaluation utilizing participant AMI data, and consistent with a Stipulation reached among stakeholders and the Program Administrators. Specifically, the parties have agreed to work collaboratively to develop an Illinois-specific advanced thermostat evaluation framework that utilizes AMI data, for consideration in updating the IL-TRM as soon as feasible, but no later than completing the evaluation in time for the 2021 IL-TRM Version 9.0, if practicable and, for Ameren Illinois, in a manner consistent with the timing of its AMI installation schedule.

$EER = (-0.02 * SEER\_exist^2) + (1.12 * SEER\_exist)$ [533]

If SEER or EER rating unavailable use:

| Cooling System | EER[534] |
|---|---|
| Air Source Heat Pump | 7.5 |
| Central AC | |

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 34%[535]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[536]

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

$\Delta kW_{SSP}$ = 100% *( 6.3% * 33,600 * (1/7.5)/1000) * 100% * 34%
= 0.096 kW

$\Delta kW_{PJM}$ = 100% * (6.3% * 33,600 * (1/7.5)/1000) * 100% * 23.3%
= 0.066 kW

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

Where:

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

| Heating fuel | %FossilHeat |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 97%[537] |

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below[538].

533 From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

534 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See ‘AIC HVAC Metering Study Memo FINAL 2_28_2018’.

535 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.)

536 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.)

537 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”

538 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

| 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:

ΔTherms = 1.0 * 1005 * 5.6% * 100% * 100%

= 56.28 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-ADTH-V03-190101**

**REVIEW DEADLINE: 1/1/2020**

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.

## 5.3.17 Gas High Efficiency Combination Boiler

### Description

Space heating boilers are pressure vessels that transfer heat to water for use in space heating. Boilers either heat water using a heat exchanger that works like an instantaneous water heater or by adding/connecting a separate tank with an internal heat exchanger to the boiler. A combination boiler contains a separate heat exchanger that heats water for domestic hot water use. Qualifying combination boilers must be whole-house units used for both space heating and domestic water heating with one appliance and energy source. Only participants who have a natural gas account with a participating natural gas utility are eligible for this rebate.

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

### Definition of Efficient Equipment

The efficient condition is a condensing combination boiler unit with boiler AFUE of 90% or greater. The combination boiler must have a sealed combustion unit and be capable of modulating the firing rate and must be accompanied by a programmed outdoor reset control.[539] Measures that do not qualify for this incentive include boilers with a storage tank and redundant or backup boilers.

### Definition of Baseline Equipment

The baseline condition is a boiler with the federal minimum of 82% AFUE and a residential, natural gas-fueled, 0.5803 UEF storage water heater.

In 2021, the federal minimum residential boiler efficiency is scheduled to increase to 84% AFUE.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 21.5 years.[540]

### Deemed Measure Cost

The incremental measure cost is assumed to be $3,522[541]

### Loadshape

N/A

### Coincidence Factor

N/A

[539] In a 2015 study, the Cadmus Group team conducted an analysis of optimal outdoor reset curves and discovered that "a boiler in Massachusetts with well-programmed outdoor reset controls could see an operating efficiency improvement of up to 3 to 4 percentage points from the average efficiency of 88.4% observed".

[540] US Department of Energy, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." February 10, 2015. Table 8.2.1, p. 8-23. The document's definition of furnaces includes hot water boilers with firing rates of less than 300,000 Btu/h.

[541] Northeast Energy Efficiency Partnerships. Incremental Cost Study Report. September 23, 2011. Incremental measure cost of $2,791.00 for a combination boiler and $2,461.00 for a high efficiency boiler sized at 110 Mbh. The percentage increase is applied to the current boiler incremental cost to provide a combination boiler cost of $3,521.72.

**Algorithm**

## CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

$$\Delta Therms = \Delta Therm_{Boiler} + \Delta Therm_{WH}$$

$$\Delta Therms_{Boiler} = (EFLH * CAPInput * (AFUE(eff) / AFUE(base) - 1)) / 100000$$

$$\Delta Therms_{WH} = (1/UEF_{Base} - 1/UEF_{Eff}) * (GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000$$

Where:

CAPInput = Gas Furnace input capacity (Btuh)

= Actual

EFLH = Equivalent Full Load Hours for gas heating

| Climate Zone (City based upon) | EFLH[542] |
|---|---|
| 1 (Rockford) | 1022 |
| 2 (Chicago) | 976 |
| 3 (Springfield) | 836 |
| 4 (Belleville) | 645 |
| 5 (Marion) | 656 |
| Weighted Average[543] | 928 |

$AFUE_{Exist}$ = Existing boiler annual fuel utilization efficiency rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 61.6 AFUE%.[544]

$AFUE_{Base}$ = Baseline boiler annual fuel utilization efficiency rating

= 82%

$AFUE_{Eff}$ = Efficent boiler annual fuel utilization efficiency rating

= Actual. If unknown, use defaults dependent[545] on tier as listed below:

[542] Full load hours for Chicago, are based on findings in 'Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.
[543] Weighted based on number of occupied residential housing units in each zone.
[544] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
[545] Default values per tier selected based upon the average AFUE value for the tier range except for the top tier where the minimum is used due to proximity to the maximum possible.

| Measure Type | $AFUE_{Eff}$ |
|---|---|
| AFUE ≥ 90% | 92.5% |
| AFUE ≥ 95% | 95% |

$UEF_{Base}$ = Uniform Energy Factor rating for baseline equipment

= For ≤55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

= For >55 gallons: 0.7897 − (0.0004 × storage capacity in gallons)

= If tank size unknown for SF assume 40 gallons and $UEF_{Base}$ of 0.58

= If tank size unknown for MF assume 30 gallons and $UEF_{Base}$ of 0.54

Use Multifamily if: Building meets utility's definition for multifamily

$UEF_{Eff}$ =Uniform Energy Factor rating for efficient combination boiler. This is assumed consistent with a condensing instantaneous gas-fired water heater.

= 0.933[546]

GPD = Gallons per day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[547]

= 17.6

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[548] |
| Multifamily - Deemed | 2.1[549] |
| Custom | Actual Occupancy or Number of Bedrooms[550] |

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year, on average

$\gamma_{Water}$ = Specific weight of water

= 8.33 pounds per gallon

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municipal system

= 54°F[551]

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546 Average Uniform Energy Factor from DOE CCMS of condensing instantaneous gas-fired water heaters. The water heater portion of a gas high efficiency combination boiler is essentially a tankless water heater.

547 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

548 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

549 Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

550 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

551 US DOE Building America Program. Building America Analysis Spreadsheet.

1.0 = Heat capacity of water (1 Btu/lb*°F)

For example, a Rockford single-family home installing a 80,000 Btuh condensing combination boiler unit with boiler AFUE of 95%:

$\Delta Therms_{Boiler}$ = (1022 * 80,000 * (0.95/0.82 - 1))/100000

$\Delta Therms_{WH}$ = (1/0.5803 – 1/0.933) * (17.6 * 2.56 * 365.25 * 8.33 * (125-54) *1.0 )/100,000

ΔTherms = 129.6 + 63.4

= 193.0 Therms

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

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-COMB-V01-190101**

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

# 5.4 Hot Water End Use

## 5.4.1 Domestic Hot Water Pipe Insulation

### Description

This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to the first length of both the hot and cold pipe up to the first elbow. This is the most cost effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow which acts as a heat trap. Insulating this length therefore helps reduce standby losses. Default savings are provided per 3ft length and are appropriate up to 6ft of the hot water pipe and 3ft of the cold.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient case is installing pipe wrap insulation to a length of hot water pipe.

### Definition of Baseline Equipment

The baseline is an un-insulated hot water pipe.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years[552].

### Deemed Measure Cost

The measure cost including material and installation is assumed to be $3 per linear foot[553].

### Loadshape

Loadshape C53 - Flat

### Coincidence Factor

This measure assumes a flat loadshape since savings relate to reducing standby losses and as such the coincidence factor is 1.

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

For electric DHW systems:

$$\Delta kWh = ((C_{exist} / R_{exist} - C_{new} / R_{new}) ) * L * \Delta T * 8{,}766) / \eta DHW / 3412$$

Where:

Rexist = Pipe heat loss coefficient of uninsulated pipe (existing) [(hr-°F-ft)/Btu]

552 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
553 Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

= 1.0[554]

Rnew = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft)/Btu]

= Actual (1.0 + R value of insulation)

L = Length of pipe from water heating source covered by pipe wrap (ft)

= Actual

$C_{exist}$ = Circumference of pipe (ft) (Diameter (in) * π/12)

= Actual (0.5” pipe = 0.131ft, 0.75” pipe = 0.196ft)

$C_{new}$ = Circumference of pipe (ft) (Diameter (in) * π/12)

= Actual (0.5” pipe and 3/8” foam ((0.5 + 3/8 + 3/8) * π/12) = .327 ft)

ΔT = Average temperature difference between supplied water and outside air temperature (°F)

= 60°F [555]

8,766 = Hours per year

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [556]

3412 = Conversion from Btu to kWh

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

ΔkWh = (($C_{exist}$ / $R_{exist}$ – $C_{new}$ / $R_{new}$) * L * ΔT * 8,766) / ηDHW / 3412

= ((0.196/1 - 0.327/5) * 5 * 60 * 8766) / 0.98 /3412

= 106 kWh

If inputs above are not available the following default per 3ft R-5 length can be used for up to 6 ft length on the hot pipe and 3 ft on the cold pipe.

ΔkWh = (($C_{exist}$ / $R_{exist}$ – $C_{new}$ / $R_{new}$) * L * ΔT * 8,766) / ηDHW / 3412

= ((0.196/1 - 0.327/5) * 3 * 60 * 8766) / 0.98 /3412

= 64kWh per 3ft length

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW **=** ΔkWh / 8766

Where:

ΔkWh = kWh savings from pipe wrap installation

8766 = Number of hours in a year (since savings are assumed to be constant over year).

[554] Navigant Consulting Inc., April 2009; “Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets”, p77.

[555] Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

[556] Electric water heaters have recovery efficiency of 98%.

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

ΔkW = 106/8766

= 0.0121kW

If inputs above are not available the following default per 3ft R-4 length can be used for up to 6 ft length on the hot pipe and 3 ft on the cold pipe.

ΔkW = 64/8766

= 0.0073 kW

**NATURAL GAS SAVINGS**

For Natural Gas DHW systems:

$$\Delta Therm = ((C_{exist} / R_{exist} - C_{new} / R_{new}) * L * \Delta T * 8,766) / \eta DHW / 100,000$$

Where:

ηDHW = Recovery efficiency of gas hot water heater

= 0.78 [557]

Other variables as defined above

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

ΔTherm = ((0.196/1 - 0.327/5) * 5 * 60 * 8766) / 0.78 / 100,000

= 4.40 therms

If inputs above are not available the following default per 3ft R-4 length can be used for up to 6ft length on the hot pipe and 3ft on the cold pipe.

$$\Delta Therm = ((C_{exist} / R_{exist} - C_{new} / R_{new}) * L * \Delta T * 8,766) / \eta DHW / 100,000$$

= ((0.196/1 - 0.327/5) * 3 * 60 * 8766) / 0.78 /100,000

= 2.64 therms per 3ft length

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-PINS-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

[557] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%

## 5.4.2 Gas Water Heater

### DESCRIPTION

This measure characterizes:

a) Time of sale or new construction:
The purchase and installation of a new efficient gas-fired water heater, in place of a Federal Standard unit in a residential setting. Savings are provided for power-vented, condensing storage, and whole-house tankless units meeting specific Uniform Energy Factor (UEF) criteria.

b) Early replacement:
The early removal of an existing functioning natural gas water heater from service, prior to its natural end of life, and replacement with a new high efficiency unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a residential gas-fired storage water heater or tankless water heater meeting ENERGY STAR criteria.[558]

| Water Heater Type | Water Heater Volume (gallons) | Minimum Uniform Energy Factor |
|---|---|---|
| Gas Storage | ≤ 55 | ≥ 0.64 |
| | > 55 | ≥ 0.78 |
| Gas Instantaneous | All | ≥ 0.87 |

### DEFINITION OF BASELINE EQUIPMENT

Time of Sale or New Construction: The baseline equipment is assumed to be a new, gas-fired storage residential water heater meeting minimum Federal efficiency standards. For storage water heaters with a storage capacity equal to or less than 55 gallons, the Federal energy factor requirement is calculated as 0.6483 – (0.0017 * storage capacity in gallons) and 0.7897 − (0.0004 × storage capacity in gallons) for greater than 55 gallon storage water heaters.[559] For a 40-gallon storage water heater this would be 0.58 UEF.

Early Replacement: The baseline is the efficiency of the existing gas water heater for the remaining useful life of the unit and the efficiency of a new gas water heater of the same type meeting minimum Federal efficiency standards for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.[560]

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[558] ENERGY STAR Product Specification for Residential Water Heaters, Version 3.2, effective April 16, 2015

[559] Minimum Federal standard as of 4/16/2015.

[560] DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14. Note: This source is used to support this category in aggregate. For all water heaters, life expectancy will depend on local variables such as water chemistry and homeowner maintenance. Some categories, including condensing storage and tankless water heaters do not yet have sufficient field data to support separate values. Preliminary data show lifetimes may exceed 20 years, though this has yet to be sufficiently demonstrated.

For early replacement: Remaining life of existing equipment is assumed to be 4 years[561].

**DEEMED MEASURE COST**

Time of Sale or New Construction:

The incremental capital cost for this measure is dependent on the type of water heater as listed below[562].

Early Replacement: The full installed cost is provided in the table below. The assumed deferred cost (after 4 years) of replacing existing equipment with a new baseline unit is assumed to be $650[563]. This cost should be discounted to present value using the nominal discount rate.

| Water heater Type | Incremental Cost | Full Install Cost |
|---|---|---|
| Gas Storage | $400 | $1014 |
| Condensing gas storage | $685 | $1299 |
| Tankless whole-house unit | $605 | $1219 |

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

Time of Sale or New Construction:

$$\Delta Therms = (1/UEF_{BASE} - 1/UEF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0)/100{,}000$$

Early replacement[564]:

ΔTherms for remaining life of existing unit (1st 3.7 years for gas storage unit and 1st 6.7 years for gas tankless unit):

$$= (1/UEF_{EXISTING} - 1/UEF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0)/100{,}000$$

561 Assumed to be one third of effective useful life

562 Source for cost info; DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14.

563 The deemed install cost of a Gas Storage heater is based upon DCEO Efficient Living Program Data for a sample size of 157 gas water heaters, and applying inflation rate of 1.91%.

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

ΔTherms for remaining measure life (next 7.3 years for gas storage unit and next 13.3 years for gas tankless unit):

$$= (1/ UEF_{BASE} - 1/UEF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0 )/100,000$$

Where:

UEF_Baseline = Uniform Energy Factor rating of standard storage water heater according to federal standards[565]

= For gas storage water heaters ≤55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

= For gas storage water heaters >55 gallons: 0.7897 − (0.0004 × storage capacity in gallons)

= If tank size is unknown, assume 0.563 for a gas storage water heater with a 50-gallon storage capacity

UEF_Efficient = Uniform Energy Factor Rating for efficient equipment

= Actual. If Tankless whole-house multiply rated efficiency by 0.91[566]. If unknown assume 0.64 for gas storage water heaters ≤55 gallons, 0.78 for gas storage water heaters >55 gallons, and 0.79 for gas tankless water heaters[567]

UEF_Existing = Uniform Energy Factor rating for existing equipment

= Use actual UEF rating where it is possible to measure or reasonably estimate.

= if unknown assume 0.52 [568]

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[569]

= 17.6

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[570] |
| Multifamily - Deemed | 2.1[571] |
| Custom | Actual Occupancy or Number of Bedrooms[572] |

565 Minimum Federal standard as of 4/16/2015

566 The disconnect between rated energy factor and in-situ energy consumption is markedly different for tankless units due to significantly higher contributions to overall household hot water usage from short draws. In tankless units the large burner and unit heat exchanger must fire and heat up for each draw. The additional energy losses incurred when the mass of the unit cools to the surrounding space in-between shorter draws was found to be 9% in a study prepared for Lawrence Berkeley National Laboratory by Davis Energy Group, 2006. “Field and Laboratory Testing of Tankless Gas Water Heater Performance” Due to the similarity (storage) between the other categories and the baseline, this derating factor is applied only to the tankless category.

567 ENERGY STAR Product Specification for Residential Water Heaters, Version 3.2, effective April 16, 2015.

568 Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.

569 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

570 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

571 Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

572 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

| | |
|---|---|
| | Use Multifamily if: Building meets utility's definition for multifamily |
| 365.25 | = Days per year, on average |
| γWater | = Specific Weight of water |
| | = 8.33 pounds per gallon |
| $T_{OUT}$ | = Tank temperature |
| | = 125°F |
| $T_{IN}$ | = Incoming water temperature from well or municipal system |
| | = 54°F[573] |
| 1.0 | = Heat Capacity of water (1 Btu/lb*°F) |

For example, a 40 gallon condensing gas storage water heater, with a uniform energy factor of 0.80 in a single family house:

ΔTherms = (1/0.58 - 1/0.80) * (17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1) / 100,000

= 46.15 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-GWHT-V08-190101**

**REVIEW DEADLINE: 1/1/2022**

[573] US DOE Building America Program. Building America Analysis Spreadsheet.

## 5.4.3 Heat Pump Water Heaters

### DESCRIPTION

The installation of a heat pump domestic hot water heater in place of a standard electric water heater in a home. Savings are presented dependent on the heating system installed in the home due to the impact of the heat pump water heater on the heating loads.

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

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an ENERGY STAR Heat Pump domestic water heater[574].

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a new electric water heater meeting federal minimum efficiency standards[575], dependent on the storage volume (in gallons) of the water heater.

For units ≤55 gallons – resistance storage unit with efficiency: 0.9307 – (0.0002 * rated volume in gallons)

For units >55 gallons – assume a 50 gallon resistance tank baseline[576] i.e. 0.9207 UEF.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[577]

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[578]. See section below for detail.

### DEEMED MEASURE COST

For Time of Sale or New Construction the incremental installation cost (including labor) should be used. Defaults are provided below[579]. Actual efficient costs can also be used although care should be taken as installation costs can vary significantly due to complexities of a particular site.

For retrofit costs, the actual full installation cost should be used (default provided below if unknown).

| Capacity | Efficiency Range | Baseline Installed Cost | Efficient Installed Cost | Incremental Installed Cost |
|---|---|---|---|---|
| ≤55 gallons | <2.6 UEF | $1,032 | $2,062 | $1,030 |
| | ≥2.6 UEF | $1,032 | $2,231 | $1,199 |
| >55 gallons | <2.6 UEF | $1,319 | $2,432 | $1,113 |

574 If the water heater does not have a UEF rating, but a EF rating, revert to using the previous version of this measure.
575 Minimum Federal Standard as of 4/1/2015, and updated in a Supplemental Notice of Proposed Rulemaking in 2016 assuming medium draw pattern.
576 A 50 gallon volume tank for the baseline is assumed to capture market practice of using larger heat pump water heaters to achieve greater efficiency of the heat pump cycle and preventing the unit from going in electric resistance mode.
577 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
578 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.
579 Costs for <2.6 UEF are based upon averages from the NEEP Phase 3 Incremental Cost Study. The assumption for higher efficiency tanks is based upon averaged from NEEP Phase 4 Incremental Cost Study. See 'HPWH Cost Estimation.xls' for more information.

| Capacity | Efficiency Range | Baseline Installed Cost | Efficient Installed Cost | Incremental Installed Cost |
|---|---|---|---|---|
| | ≥2.6 UEF | $1,319 | $3,116 | $1,797 |

**LOADSHAPE**

Loadshape R03 - Residential Electric DHW

**COINCIDENCE FACTOR**

The summer Peak Coincidence Factor is assumed to be 12%.[580]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWh = $(((1/UEF_{BASE} – 1/UEF_{EFFICIENT})$ * GPD * Household * 365.25 * γWater * $(T_{OUT} – T_{IN})$ * 1.0) / 3412) + kWh_cooling - kWh_heating

Where:

$UEF_{BASE}$ = Uniform Energy Factor (efficiency) of standard electric water heater according to federal standards[581]:

For <=55 gallons: 0.96 – (0.0003 * rated volume in gallons)

For >55 gallons: 2.057 – (0.00113 * rated volume in gallons)

= If unknown volume, use 0.945 for a 50 gallon tank, the most common size for HPWH

$UEF_{EFFICIENT}$ = Uniform Energy Factor (efficiency) of Heat Pump water heater

= Actual

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[582]

= 17.6

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[583] |
| Multifamily - Deemed | 2.1[584] |
| Custom | Actual Occupancy or |

[580] Calculated from Figure 8 "Combined six-unit summer weekday average electrical demand" in FEMP study; 'Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters' as (average kW usage during peak period * hours in peak period) / [(annual kWh savings / FLH) * hours in peak period] = (0.1 kW * 5 hours) / [(2100 kWh (default assumptions) / 2533 hours) * 5 hours] = 0.12

[581] Minimum Federal Standard as of 1/1/2015.

[582] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[583] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[584] Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

| Household Unit Type | Household |
|---|---|
| | Number of Bedrooms[585] |

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municiple system

= 54°F[586]

1.0 = Heat Capacity of water (1 Btu/lb*°F)

3412 = Conversion from Btu to kWh

kWh_cooling[587] = Cooling savings from conversion of heat in home to water heat

=(((((GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412) – ((1/ $UEF_{NEW}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)) * LF * 27%) / $COP_{COOL}$) * LM

Where:

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location

= 0.0 for installation in an unconditioned space

27% = Portion of reduced waste heat that results in cooling savings[588]

$COP_{COOL}$ = COP of central air conditioning

= Actual, if unknown, assume 2.8 [589]

LM = Latent multiplier to account for latent cooling demand

= 1.33 [590]

kWh_heating = Heating cost from conversion of heat in home to water heat (dependent on heating fuel)

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585 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

586 US DOE Building America Program. Building America Analysis Spreadsheet.

587 This algorithm calculates the heat removed from the air by subtracting the HPWH electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the HP unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling and latent cooling demands.

588 REMRate determined percentage (27%) of lighting savings that result in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

589 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.

590 A sensible heat ratio (SHR) of 0.75 corresponds to a latent multiplier of 4/3 or 1.33. SHR of 0.75 for typical split system from page 10 of "Controlling Indoor Humidity Using Variable-Speed Compressors and Blowers" by M. A. Andrade and C. W. Bullard, 1999.

= (((((GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412) –

((1/ $UEF_{NEW}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)) * LF * 49%) / $COP_{HEAT}$) * (1 - %NaturalGas)

Where:

49% = Portion of reduced waste heat that results in increased heating load[591]

$COP_{HEAT}$ = COP of electric heating system

= actual. If not available use[592]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[593] | N/A | N/A | 1.28 |

For example, a 2.0 UEF heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning (SEER 10.5) in Belleville:

ΔkWh = [(1 / 0.945 – 1 / 2.0) * 17.6 * 2.56 * 365.25* 8.33 * (125 – 54)] / 3412 + 188.9 - 0

= 1781kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / Hours * CF

Where:

Hours = Full load hours of water heater

= 2533 [594]

CF = Summer Peak Coincidence Factor for measure

= 0.12 [595]

591 REMRate determined percentage (49%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

592 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.

593 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.

594 Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

595 Calculated from Figure 8 "Combined six-unit summer weekday average electrical demand" in FEMP study; 'Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters' as (average kW usage during peak period * hours in peak period) / [(annual kWh savings / FLH) * hours in peak period] = (0.1 kW * 5 hours) / [(2100 kWh / 2533 hours) * 5 hours] = 0.12

For example, a 2.0 UEF heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning in Belleville:

kW = 1838 / 2533 * 0.12

= 0.087kW

**NATURAL GAS SAVINGS**

ΔTherms = - ((((GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412) – (((GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412) / $UEF_{EFFICIENT}$)) * LF * 49% * 0.03412) / ηHeat) * %NaturalGas

Where:

ΔTherms = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat.[596]

0.03412 = conversion factor (therms per kWh)

ηHeat = Efficiency of heating system

= Actual.[597] If not available use 70%.[598]

%NaturalGas = Factor dependent on heating fuel:

| Heating System | %NaturalGas |
|---|---|
| Electric resistance or heat pump | 0% |
| Natural Gas | 100% |
| Unknown heating fuel[599] | 87% |

Other factors as defined above

For example, a 2.0 COP heat pump water heater in conditioned space, in a single family home with gas space heat (70% system efficiency):

ΔTherms = -((((17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1.0) / 3412) – (17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1.0 / 3412 / 2.0)) * 1 * 0.49 * 0.03412) / (0.7 * 1)

= - 34.1 therms

[596] This is the additional energy consumption required to replace the heat removed from the home during the heating season by the heat pump water heater. kWh_heating (electric resistance) is that additional heating energy for a home with electric resistance heat (COP 1.0). This formula converts the additional heating kWh for an electric resistance home to the MMBtu required in a Natural Gas heated home, applying the relative efficiencies.

[597] 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 'DistributionEfficiencyTable-BlueSheet.pdf') or by performing duct blaster testing.

[598] 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

[599] 2010 American Community Survey.

**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<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% 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[600].

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-HPWH-V07-190101**

**REVIEW DEADLINE: 1/1/2022**

[600] 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.

## 5.4.4 Low Flow Faucet Aerators

**DESCRIPTION**

This measure relates to the installation of a low flow faucet aerator in a household kitchen or bath faucet fixture.

This measure may be used for units provided through Efficiency Kits however the in service rate for such measures should be derived through evaluation results specifically for this implementation methodology.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI, KITS.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a low flow faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.2 GPM or greater, or a standard kitchen faucet aerator rated at 2.2 GPM or greater.

Average measured flow rates are used in the algorithm and are lower, reflecting the penetration of previously installed low flow fixtures (and therefore the freerider rate for this measure should be 0), use of the faucet at less than full flow, debris buildup, and lower water system pressure than fixtures are rated at.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 10 years.[601]

**DEEMED MEASURE COST**

For time of sale or new construction the incremental cost for this measure is $3[602] or program actual.

For faucet aerators provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $8[603] for Direct Install and $3 for Efficiency Kits.

**LOADSHAPE**

Loadshape R03 - Residential Electric DHW

**COINCIDENCE FACTOR**

The coincidence factor for this measure is assumed to be 2.2%.[604]

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[601] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[602] 2011, Market research average of $3.

[603] Includes assess and install labor time of $5 (20min @ $15/hr)

[604] Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% *180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[605] (unless faucet type is unknown, then it is per household).

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

| DHW fuel | %ElectricDHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 16%[606] |

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used." This includes the effect of existing low flow fixtures and therefore the freerider rate for this measure should be 0.

= If unknown assume values in table below, or custom based on metering studies[607], or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[608]

| Faucet Type | GPM[609] |
|---|---|
| Kitchen | 1.63 |
| Bathroom | 1.53 |
| If faucet location unknown | 1.58 |

GPM_low = Average flow rate, in gallons per minute, of the low-flow faucet aerator "as-used"

[605] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.
[606] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used
[607] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.
[608] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf
[609] Based on flow meter bag testing conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

= 0.94[610] or custom based on metering studies[611] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[612]

L_base = Average baseline daily length faucet use per capita for faucet of interest in minutes

= if available custom based on metering studies, if not use:

| Faucet Type | L_base (min/person/day) |
|---|---|
| Kitchen | 4.5[613] |
| Bathroom | 1.6[614] |
| If faucet location unknown (total for household): Single-Family except mobile homes | 9.0[615] |
| If location unknown (total for household): Multifamily and mobile homes | 6.9[616] |
| If faucet location and building type unknown (total for household) | 8.3[617] |

L_low = Average retrofit daily length faucet use per capita for faucet of interest in minutes

= if available custom based on metering studies, if not use:

| Faucet Type | L_low (min/person/day) |
|---|---|
| Kitchen | 4.5[618] |
| Bathroom | 1.6[619] |
| If faucet location unknown (total for household): Single-Family except mobile homes | 9.0[620] |
| If faucet location unknown (total for household): | 6.9[621] |

610 Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7(see source table at end of characterization). This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

611 Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

612 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265.

613 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and Multifamily homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

614 Ibid.

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

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

617 Unknown is 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.

618 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

619 Ibid.

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

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

| Faucet Type | L_low (min/person/day) |
|---|---|
| Multifamily | |
| If faucet location and building type unknown (total for household) | 8.3[622] |

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[623] |
| Multi-Family - Deemed | 2.1[624] |
| Household type unknown | 2.42[625] |
| Custom | Actual Occupancy or Number of Bedrooms[626] |

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days in a year, on average.

DF = Drain Factor

| Faucet Type | Drain Factor[627] |
|---|---|
| Kitchen | 75% |
| Bath | 90% |
| Unknown | 79.5% |

FPH = Faucets Per Household

| Faucet Type | FPH |
|---|---|
| Kitchen Faucets Per Home (KFPH) | 1 |
| Bathroom Faucets Per Home (BFPH): Single-Family except mobile homes | 2.83[628] |
| Bathroom Faucets Per Home (BFPH): Multifamily and mobile homes | 1.5[629] |
| If faucet location unknown (total for household): Single-Family except mobile homes | 3.83 |
| If faucet location unknown (total for household): Multifamily and mobile homes | 2.5 |

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622 Unknown is 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.

623 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

624 Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

625 Unknown is 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.

626 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

627 Because faucet usages are at times dictated by volume, only usage of the sort that would go straight down the drain will provide savings. VEIC is unaware of any metering study that has determined this specific factor and so through consensus with the Illinois Technical Advisory Group have deemed these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*0.75)+(0.3*0.9)=0.795.

628 Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

629 Ibid.

| Faucet Type | FPH |
|---|---|
| If faucet location and building type unknown (total for household) | 3.42[630] |

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

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (86 – 54.1)) / (0.98 * 3412)

= 0.0795 kWh/gal (Bath), 0.0969 kWh/gal (Kitchen), 0.0919 kWh/gal (Unknown)

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°F)

WaterTemp = Assumed temperature of mixed water

= 86F for Bath, 93F for Kitchen 91F for Unknown[631]

SupplyTemp = Assumed temperature of water entering house

= 54.1F [632]

RE_electric = Recovery efficiency of electric water heater

= 98% [633]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below

[630] Unknown is 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.

[631] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*93)+(0.3*86)=0.91.

[632] US DOE Building America Program. Building America Analysis Spreadsheet.

[633] Electric water heaters have recovery efficiency of 98%.http://www.ahridirectory.org/ahridirectory/pages/home.aspx

| Selection | ISR |
|---|---|
| Direct Install - Single Family | 0.95[634] |
| Direct Install –Multifamily Kitchen | 0.91[635] |
| Direct Install –Multifamily Bathroom | 0.95[636] |
| Efficiency Kit Bathroom Aerator | 0.61[637] |
| Efficiency Kit Kitchen Aerator | 0.58[638] |
| Distributed School Efficiency Kit Bathroom Aerator | 0.30[639] |
| Distributed School Efficiency Kit Kitchen Aerator | 0.31[640] |

Use Multifamily if: Building meets utility's definition for multifamily

For example, a direct installed kitchen low flow faucet aerator in an individual electric DHW home:

ΔkWh = 1.0 * (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.0969 * 0.95
= 200 kWh

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

ΔkWh = 1.0 * (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.0795 * 0.95
= 33.0 kWh

For example, a direct installed low flow faucet aerator in unknown faucet in an individual electric DHW home:

ΔkWh = 1.0 * (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.0919 * 0.95
= 97.6 kWh

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.

$\Delta kWh_{water}$ = ΔWater (gallons) / 1,000,000 * $E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)
=5010[641]

[634] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8
[635] Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report DRAFT 2013-01-28
[636] Ibid.
[637] A weighted ISR was found by weighting Nicor and Ameren efficiency kit program uptake and their previously found ISRs. This analysis can be found in Faucet Aerators and Showerheads Weighted Average ISR IL TRM.xlsx.
[638] A weighted ISR was found by weighting Nicor and Ameren efficiency kit program uptake and their previously found ISRs. This analysis can be found in Faucet Aerators and Showerheads Weighted Average ISR IL TRM.xlsx.
[639] Opinion Dynamics and Cadmus. Ameren Illinois Company Transition Period Impact Evaluation Report. Volume 1 – Impact Evaluation Results. April 30, 2018. School Kits Program.
[640] ibid
[641] This factor includes 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

For example, a direct installed kitchen low flow aerator in an single family home

ΔWater (gallons) = (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.95

= 2068 gallons

$\Delta kWh_{water}$ = 2068/1000000 * 5010

=10.4 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / Hours * CF

Where:

ΔkWh = calculated value above.

Hours = Annual electric DHW recovery hours for faucet use per faucet

= ((GPM_base * L_base) * Household/FPH * 365.25 * DF ) * 0.545[642] / GPH

| Building Type | Faucet location | Calculation | Hours per faucet |
|---|---|---|---|
| Single Family | Kitchen | ((1.63 * 4.5) * 2.56/1 * 365.25 * 0.75) * 0.545 / 27.4 | 102 |
| | Bathroom | ((1. 53 * 1.6) * 2.56/2.83 * 365.25 * 0.9) * 0.545 / 27.4 | 14 |
| | Unknown | ((1. 58* 9.0) * 2.56/3.83 * 365.25 * 0.795) * 0.545 / 27.4 | 55 |
| Multifamily | Kitchen | ((1. 63 * 4.5) * 2.1/1 * 365.25 * 0.75) * 0.545 / 27.4 | 84 |
| | Bathroom | ((1. 53* 1.6) * 2.1/1.5 * 365.25 * 0.9) * 0.545 / 27.4 | 22 |
| | Unknown | ((1. 58 * 6.9) * 2.1/2.5 * 365.25 * 0.795) * 0.545 / 27.4 | 53 |

GPH = Gallons per hour recovery of electric water heater calculated for 70.9F temp rise (125-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.4

CF = Coincidence Factor for electric load reduction

= 0.022[643]

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

ΔkW =200/110 * 0.022

= 0.04 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_gas * ISR

Where:

[642] 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90F mixed faucet water.

[643] Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% *180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022

%FossilDHW = proportion of water heating supplied by Natural Gas heating

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[644] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00341 Therm/gal for SF homes (Bath), 0.00415 Therm/gal for SF homes (Kitchen), 0.00394 Therm/gal for SF homes (Unknown)

= 0.00397 Therm/gal for MF homes (Bath), 0.00484 Therm/gal for MF homes (Kitchen), 0.00459 Therm/gal for MF homes (Unknown)

RE_gas = Recovery efficiency of gas water heater

= 78% For individual water heater[645]

= 67% For shared water heater[646]

If unknown, use individual water heater value for single family, use shared water heater value for multifamily. Use multifamily if building meets utility's definition for multifamily.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

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

ΔTherms = 1.0 * (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.00415 * 0.95

= 8.58 Therms

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

ΔTherms = 1.0 * (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.003974 * 0.95

= 1.64 Therms

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

ΔTherms = 1.0 * (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.00394 * 0.95

= 4.18 Therms

## WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * ISR

Variables as defined above

644 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

645 DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

646 Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

For example, a direct-installed kitchen low flow aerator in a single family home

ΔWater (gallons) = (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.95

= 2068 gallons

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

ΔWater (gallons) = (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.95

= 413 gallons

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

ΔWater (gallons) = (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.95

= 1062 gallons

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**SOURCES**

| Source ID | Reference |
|---|---|
| 1 | 2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011. |
| 2 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |
| 3 | 1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999. |
| 4 | 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. |
| 5 | 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011. |
| 6 | 2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |

**MEASURE CODE: RS-HWE-LFFA-V07-190101**

**REVIEW DEADLINE: 1/1/2022**

## 5.4.5 Low Flow Showerheads

### Description

This measure relates to the installation of a low flow showerhead in a single or multi-family household.

This measure may be used for units provided through Efficiency Kits; however the in service rate for such measures should be derived through evaluation results specifically for this implementation methodology.

This measure was developed to be applicable to the following program types: TOS, RF, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a low flow showerhead rated at least 0.5 gallons per minute (GPM) less than the existing showerhead. Savings are calculated on a per showerhead fixture basis.

### Definition of Baseline Equipment

For Direct install programs, the baseline condition is assumed to be a standard showerhead rated at 2.0 GPM or greater.

For retrofit and time-of-sale programs, the baseline condition is assumed to be a representative average of existing showerhead flow rates of participating customers including a range of low flow showerheads, standard-flow showerheads, and high-flow showerheads.

Average measured flow rates are used in the algorithm and are lower, reflecting the penetration of previously installed low flow fixtures (and therefore the freerider rate for this measure should be 0), use of the shower at less than full flow, debris buildup, and lower water system pressure than fixtures are rated at.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years.[647]

### Deemed Measure Cost

For time of sale or new construction the incremental cost for this measure is $7[648] or program actual.

For low flow showerheads provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $12[649] for Direct Install and $7 for Efficiency Kits.

### Loadshape

Loadshape R03 - Residential Electric DHW

### Coincidence Factor

The coincidence factor for this measure is assumed to be 2.78%.[650]

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[647] Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multifamily.
[648] Market research average of $7.
[649] Includes assess and install labor time of $5 (20min @ $15/hr)
[650] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Note these savings are per showerhead fixture

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

| DHW fuel | %ElectricDHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 16%[651] |

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used." This includes the effect of existing low flow fixtures and therefore the freerider rate for this measure should be 0.

| Program | GPM_base |
|---|---|
| Direct-install | 2.24[652] |
| Retrofit, Efficiency Kits, NC or TOS | 2.35[653] |

GPM_low = As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaulations deviate from rated flows, see table below:

| Rated Flow |
|---|
| 2.0 GPM |
| 1.75 GPM |
| 1.5 GPM |
| Custom or Actual[654] |

L_base = Shower length in minutes with baseline showerhead

therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period, where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

651 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

652 Based on measurements conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

653 Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

654 Note that actual values may be either a) program-specific minimum flow rate, or b) program-specific evaluation-based value of actual effective flow-rate due to increased duration or temperatures. The latter increases in likelihood as the rated flow drops and may become significant at or below rated flows of 1.5 GPM. The impact can be viewed as the inverse of the throttling described in the footnote for baseline flowrate.

= 7.8 min[655]

L_low = Shower length in minutes with low-flow showerhead

= 7.8 min[656]

Household = Average number of people per household

| Household Unit Type[657] | Household |
|---|---|
| Single-Family - Deemed | 2.56[658] |
| Multi-Family - Deemed | 2.1[659] |
| Household type unknown | 2.42[660] |
| Custom | Actual Occupancy or Number of Bedrooms[661] |

Use Multifamily if: Building meets utility's definition for multifamily

SPCD = Showers Per Capita Per Day

= 0.6[662]

365.25 = Days per year, on average.

SPH = Showerheads Per Household so that per-showerhead savings fractions can be determined

| Household Type | SPH |
|---|---|
| Single-Family except mobile homes | 1.79[663] |
| Multifamily and mobile homes | 1.3[664] |
| Household type unknown | 1.64[665] |
| Custom | Actual |

Use Multifamily if: Building meets utility's definition for multifamily

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 54.1)) / (0.98 * 3412)

[655] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and Multifamily homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.
[656] Ibid.
[657] If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.
[658] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment
[659] ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx
[660] Unknown is 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.
[661] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.
[662] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[663] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
[664] Ibid.
[665] Unknown is 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.

= 0.117 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water

= 101F[666]

SupplyTemp = Assumed temperature of water entering house

= 54.1F[667]

RE_electric = Recovery efficiency of electric water heater

= 98%[668]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependant on program delivery method as listed in table below

| Selection | ISR |
|---|---|
| Direct Install - Single Family | 0.98[669] |
| Direct Install –Multifamily | 0.95[670] |
| Efficiency Kits--One showerhead kit | 0.62[671] |
| Efficiency Kits—Two showerhead kit | 0.67[672] |
| Distributed School Efficiency Kit showerhead | 0.28[673] |

Use Multifamily if: Building meets utility's definition for multifamily

For example, a direct-installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:

$$\Delta kWh = 1.0 * ((2.24 * 7.8 - 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.117 * 0.98$$

$$= 207 \text{ kWh}$$

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.

$$\Delta kWh_{water} = \Delta Water \text{ (gallons)} / 1{,}000{,}000 * E_{water\ total}$$

666 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
667 US DOE Building America Program. Building America Analysis Spreadsheet.
668 Electric water heaters have recovery efficiency of 98%.
669 Deemed values are from ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8. Alternative ISRs may be developed for program delivery methods based on evaluation results.
670 Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report FINAL 2013-06-05
671 A weighted ISR was found by weighting Nicor and Ameren efficiency kit program uptake and their previously found ISRs. This analysis can be found in Faucet Aerators and Showerheads Weighted Average ISR IL TRM.xlsx.
672 A weighted ISR was found by weighting Nicor and Ameren efficiency kit program uptake and their previously found ISRs. This analysis can be found in Faucet Aerators and Showerheads Weighted Average ISR IL TRM.xlsx.
673 Opinion Dynamics and Cadmus. Ameren Illinois Company Transition Period Impact Evaluation Report. Volume 1 – Impact Evaluation Results. April 30, 2018. School Kits Program.

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5010[674]

> For example, a direct installed 1.5 GPM low flow showerhead in a single family where the number of showers is not known:
>
> ΔWater (gallons) = ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98
>
> = 1773 gallons
>
> $\Delta kWh_{water}$ = 1773/1,000,000 * 5010
>
> = 8.9 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) * Household * SPCD * 365.25 ) * 0.712[675] / GPH

= 255 for SF Direct Install; 208 for MF Direct Install

= 267 for SF Retrofit, Efficiency Kits, NC and TOS; 219 for MF Retrofit, Efficiency Kits, NC and TOS

Use Multifamily if: Building meets utility's definition for multifamily

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.4

CF = Coincidence Factor for electric load reduction

= 0.0278[676]

> For example, a direct installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:
>
> ΔkW = 207/255 * 0.0278
>
> = .022 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD

[674] This factor includes 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[675] 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

[676] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

* 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[677] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For individual water heater[678]

= 67% For shared water heater[679]

If unknown, use individual water heater value for single family, use shared water heater value for multifamily. Use multifamily if building meets utility's definition for multifamily.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

For example, a direct installed 1.5 GPM low flow showerhead in a gas fired DHW single family home where the number of showers is not known:

ΔTherms = 1.0 * ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98

= 8.9 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

ΔWater (gallons) = ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

[677] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[678] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[679] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

For example, a direct installed 1.5 GPM low flow showerhead in a single family home where the number of showers is not known:

$$\Delta Water\ (gallons) = ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98$$

$$= 1773\ gallons$$

### Deemed O&M Cost Adjustment Calculation

N/A

### Sources

| Source ID | Reference |
|---|---|
| 1 | 2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011. |
| 2 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |
| 3 | 1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999. |
| 4 | 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. |
| 5 | 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011. |
| 6 | 2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |

### Measure Code: RS-HWE-LFSH-V06-190101

### Review Deadline: 1/1/2023

## 5.4.6 Water Heater Temperature Setback

### Description

This measure was developed to be applicable to the following program types: NC, RF, DI, KITS.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

High efficiency is a hot water tank with the thermostat reduced to no lower than 120 degrees.

### Definition of Baseline Equipment

The baseline condition is a hot water tank with a thermostat setting that is higher than 120 degrees, typically systems with settings of 130 degrees or higher. Note if there are more than one DHW tanks in the home at or higher than 130 degrees and they are all turned down, then the savings per tank can be multiplied by the number of tanks.

### Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 2 years.

### Deemed Measure Cost

The incremental cost of a setback is assumed to be $5 for contractor time, or no cost if the measure is self-installed.

### Loadshape

Loadshape R03 - Residential Electric DHW

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 1.

## Algorithm

### Calculation of Savings

### Electric Energy Savings

For homes with electric DHW tanks:

ΔkWh[680]= (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)

Where:

U = Overall heat transfer coefficient of tank (Btu/Hr-°F-$ft^2$).

= Actual if known. If unknown assume R-12, U = 0.083

A = Surface area of storage tank (square feet)

= Actual if known. If unknown use table below based on capacity of tank. If capacity

[680] Note this algorithm provides savings only from reduction in standby losses. The TAC considered avoided energy from not heating the water to the higher temperature but determined that dishwashers are likely to boost the temperature within the unit (roughly canceling out any savings), faucet and shower use is likely to be at the same temperature so there would need to be more lower temperature hot water being used (cancelling any savings) and clothes washers will only see savings if the water from the tank is taken without any temperature control. It was felt the potential impact was too small to be characterized.

unknown assume 50 gal tank; A = 24.99ft$^2$

| Capacity (gal) | A (ft$^2$)[681] |
|---|---|
| 30 | 19.16 |
| 40 | 23.18 |
| 50 | 24.99 |
| 80 | 31.84 |

Tpre = Actual hot water setpoint prior to adjustment

Tpost = Actual new hot water setpoint, which may not be lower than 120 degrees

| Default Hot Water Temperature Inputs | |
|---|---|
| Tpre | 135 |
| Tpost | 120 |

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

ISR = In service rate of measure

= Dependant on program delivery method as listed in table below

| Delivery method | ISR |
|---|---|
| Instructions provided in a Kit | To be determined through evaluation |
| All other | 1.0 |

3412 = Conversion from Btu to kWh

RE_electric = Recovery efficiency of electric hot water heater

= 0.98 [682]

A deemed savings assumption, where site specific assumptions are not available would be as follows:

ΔkWh = (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (3412 * 0.98)

= 81.6 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW **=** ΔkWh / Hours * CF

Where:

Hours = 8766

CF = Summer Peak Coincidence Factor for measure

= 1

A deemed savings assumption, where site specific assumptions are not available would be as follows:

[681] Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

[682] Electric water heaters have recovery efficiency of 98%.

ΔkW = (81.6/ 8766) * 1

ΔkW default = 0.00931 kW

**NATURAL GAS SAVINGS**

For homes with gas water heaters:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (100,000 * RE_gas)

Where

100,000 = Converts Btus to Therms (btu/Therm)

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes [683]

= 67% For MF homes[684]

Use Multifamily if: Building has shared DHW

A deemed savings assumption, where site specific assumptions are not available would be as follows:

For Single Family homes:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (RE_gas)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (100,000 * 0.78)

= 3.5 Therms

For Multi Family homes:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (RE_gas)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (100,000 * 0.67)

= 4.1 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-TMPS-V06-190101**

**REVIEW DEADLINE: 1/1/2022**

[683] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[684] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

## 5.4.7 Water Heater Wrap

### Description

This measure relates to a Tank Wrap or insulation "blanket" that is wrapped around the outside of a hot water tank to reduce stand-by losses. This measure applies only for homes that have an electric water heater that is not already well insulated. Generally this can be determined based upon the appearance of the tank.[685]

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The measure is a properly installed, R-8 or greater insulating tank wrap to reduce standby energy losses from the tank to the surrounding ambient area.

### Definition of Baseline Equipment

The baseline is a standard electric domestic hot water tank without an additional tank wrap. Gas storage water heaters are excluded due to the limitations of retrofit wrapping and the associated impacts on reduced savings and safety.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 5 years[686].

### Deemed Measure Cost

The incremental cost for this measure will be the actual material cost of procuring and labor cost of installing the tank wrap.

### Loadshape

Loadshape R03 - Residential Electric DHW

### Coincidence Factor

This measure assumes a flat loadshape and as such the coincidence factor is 1.

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

For electric DHW systems:

$$\Delta kWh = ((A_{base} / Rbase – A_{insul} / R_{insul}) * \Delta T * Hours) / (3412 * \eta DHW)$$

Where:

$R_{base}$ = Overall thermal resistance coefficient prior to adding tank wrap (Hr-°F-ft$^2$/BTU).

[685] Visually determine whether it is insulated by foam (newer, rigid, and more effective) or fiberglass (older, gives to gently pressure, and not as effective)

[686] This estimate assumes the tank wrap is installed on an existing unit with 5 years remaining life.

$R_{insul}$ = Overall thermal resistance coefficient after addition of tank wrap (Hr-°F-ft²/BTU).

$A_{base}$ = Surface area of storage tank prior to adding tank wrap (square feet)[687]

$A_{insul}$ = Surface area of storage tank after addition of tank wrap (square feet)[688]

ΔT = Average temperature difference between tank water and outside air temperature (°F)

= 60°F [689]

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

3412 = Conversion from Btu to kWh

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [690]

The following table has default savings for various tank capacity and pre and post R-VALUES.

| Capacity (gal) | Rbase | Rinsul | Abase (ft2)[691] | Ainsul (ft2)[692] | ΔkWh | ΔkW |
|---|---|---|---|---|---|---|
| 30 | 8 | 16 | 19.16 | 20.94 | 171 | 0.0195 |
| 30 | 10 | 18 | 19.16 | 20.94 | 118 | 0.0135 |
| 30 | 12 | 20 | 19.16 | 20.94 | 86 | 0.0099 |
| 30 | 8 | 18 | 19.16 | 20.94 | 194 | 0.0221 |
| 30 | 10 | 20 | 19.16 | 20.94 | 137 | 0.0156 |
| 30 | 12 | 22 | 19.16 | 20.94 | 101 | 0.0116 |
| 40 | 8 | 16 | 23.18 | 25.31 | 207 | 0.0236 |
| 40 | 10 | 18 | 23.18 | 25.31 | 143 | 0.0164 |
| 40 | 12 | 20 | 23.18 | 25.31 | 105 | 0.0120 |
| 40 | 8 | 18 | 23.18 | 25.31 | 234 | 0.0268 |
| 40 | 10 | 20 | 23.18 | 25.31 | 165 | 0.0189 |
| 40 | 12 | 22 | 23.18 | 25.31 | 123 | 0.0140 |
| 50 | 8 | 16 | 24.99 | 27.06 | 225 | 0.0257 |
| 50 | 10 | 18 | 24.99 | 27.06 | 157 | 0.0179 |
| 50 | 12 | 20 | 24.99 | 27.06 | 115 | 0.0131 |
| 50 | 8 | 18 | 24.99 | 27.06 | 255 | 0.0291 |
| 50 | 10 | 20 | 24.99 | 27.06 | 180 | 0.0206 |
| 50 | 12 | 22 | 24.99 | 27.06 | 134 | 0.0153 |
| 80 | 8 | 16 | 31.84 | 34.14 | 290 | 0.0331 |
| 80 | 10 | 18 | 31.84 | 34.14 | 202 | 0.0231 |
| 80 | 12 | 20 | 31.84 | 34.14 | 149 | 0.0170 |
| 80 | 8 | 18 | 31.84 | 34.14 | 328 | 0.0374 |
| 80 | 10 | 20 | 31.84 | 34.14 | 232 | 0.0265 |
| 80 | 12 | 22 | 31.84 | 34.14 | 173 | 0.0198 |

687 Area includes tank sides and top to account for typical wrap coverage.
688 Ibid.
689 Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.
690 Electric water heaters have recovery efficiency of 98%.
691 Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
692 Assumptions from PA TRM. $A_{insul}$ was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh / 8766 * CF$$

Where:

ΔkWh = kWh savings from tank wrap installation

8766 = Number of hours in a year (since savings are assumed to be constant over year).

CF = Summer Coincidence Factor for this measure

= 1.0

The table above has default kW savings for various tank capacity and pre and post R-values.

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-WRAP-V02-150601**

**REVIEW DEADLINE: 1/1/2022**

## 5.4.8 Thermostatic Restrictor Shower Valve

### DESCRIPTION

The measure is the installation of a thermostatic restrictor shower valve in a single or multi-family household. This is a valve attached to a residential showerhead which restricts hot water flow through the showerhead once the water reaches a set point (generally 95F or lower).

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

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a thermostatic restrictor shower valve installed on a residential showerhead.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the residential showerhead without the restrictor valve installed.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years. [693]

### DEEMED MEASURE COST

The incremental cost of the measure should be the actual program cost (including labor if applicable) or $30[694] plus $20 labor[695] if not available.

### LOADSHAPE

Loadshape R03 - Residential Electric DHW

### COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.22%.[696]

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) *

[693] Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead.

[694] Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.

[695] Estimate for contractor installation time.

[696] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022

EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

| DHW fuel | %ElectricDHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 16%[697] |

GPM_base_S = Flow rate of the basecase showerhead, or actual if available

| Program | GPM |
|---|---|
| Direct-install, device only | 2.67[698] |
| New Construction or direct install of device and low flow showerhead | Rated or actual flow of program-installed showerhead |
| Retrofit or TOS | 2.35[699] |

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

= 0.89 minutes[700]

Household = Average number of people per household

| Household Unit Type[701] | Household |
|---|---|
| Single-Family - Deemed | 2.56[702] |
| Multi-Family - Deemed | 2.1[703] |
| Household type unknown | 2.42[704] |
| Custom | Actual Occupancy or Number of Bedrooms[705] |

Use Multifamily if: Building meets utility's definition for multifamily

SPCD = Showers Per Capita Per Day

[697] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[698] Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above. Assumes low flow showerhead not included in direct installation.

[699] Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

[700] Average of the following sources: ShowerStart LLC survey; "Identifying, Quantifying and Reducing Behavioral Waste in the Shower: Exploring the Savings Potential of ShowerStart", City of San Diego Water Department survey; "Water Conservation Program: ShowerStart Pilot Project White Paper", and PG&E Work Paper PGECODHW113.

[701] If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

[702] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[703] ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

[704] Unknown is 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.

[705] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

= 0.6[706]

365.25 = Days per year, on average.

SPH = Showerheads Per Household so that per-showerhead savings fractions can be determined

| Household Type | SPH |
|---|---|
| Single-Family | 1.79[707] |
| Multifamily | 1.3[708] |
| Household type unknown | 1.64[709] |
| Custom | Actual |

Use Multifamily if: Building meets utility's definition for multifamily

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 54.1)) / (0.98 * 3412)

= 0.117 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water

= 101F [710]

SupplyTemp = Assumed temperature of water entering house

= 54.1F [711]

RE_electric = Recovery efficiency of electric water heater

= 98% [712]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependent on program delivery method as listed in table below

| Selection | ISR |
|---|---|
| Direct Install - Single Family | 0.98[713] |

[706] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[707] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
[708] Ibid.
[709] Unknown is 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.
[710] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[711] US DOE Building America Program. Building America Analysis Spreadsheet.
[712] Electric water heaters have recovery efficiency of 98%.
[713] Deemed values are from ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8. Alternative ISRs may be developed for program delivery methods based on evaluation results.

| Selection | ISR |
|---|---|
| Direct Install – Multi Family | 0.95[714] |
| Efficiency Kits | To be determined through evaluation |

Use Multifamily if: Building meets utility's definition for multifamily

> Example
>
> For example, a direct installed valve in a single-family home with electric DHW:
>
> ΔkWh = 1.0 * (2.67 * 0.89 * 2.56 * 0.6 * 365.25 / 1.79) * 0.117 * 0.98
>
> = 85 kWh

<u>Secondary kWh Savings for Water Supply and Wastewater Treatment</u>

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.

$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[715]

> For example, a direct installed thermostatic restrictor device in a home with an single family home where the number of showers is not known:
>
> ΔWater (gallons) = ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98
>
> = 730 gallons
>
> $\Delta kWh_{water}$ = 730/1,000,000 * 5010
>
> = 3.7 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device

= ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 ) * 0.712[716] / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

= 34.4 for SF Direct Install; 28.3 for MF Direct Install

= 30.3 for SF Retrofit and TOS; 24.8 for MF Retrofit and TOS

Use Multifamily if: Building meets utility's definition for multifamily

[714] Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report FINAL 2013-06-05

[715] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[716] 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

CF = Coincidence Factor for electric load reduction

= 0.0022[717]

**Example**

For example, a direct installed thermostatic restrictor device in a home with electric DHW where the number of showers is not known.

ΔkW = 85.3/34.4 * 0.0022

= 0.0055 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilDHW * ((GPM_base_S * L_showerdevice)* Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[718] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[719]

= 67% For MF homes[720]

Use Multifamily if: Building has shared DHW.

[717] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022

[718] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[719] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[720] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

**Example**

For example, a direct installed thermostatic restrictor device in a gas fired DHW single family home where the number of showers is not known:

ΔTherms = 1.0 * ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98

= 3.7 therms

#### WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

**Example**

For example, a direct installed thermostatic restrictor device in a single family home where the number of showers is not known:

ΔWater (gallons) = ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98

= 730 gallons

#### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

#### SOURCES

| Source ID | Reference |
|---|---|
| 1 | 2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011. |
| 2 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |
| 3 | 1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999. |
| 4 | 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. |
| 5 | 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011. |
| 6 | 2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |
| 8 | 2011, Lutz, Jim. "Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems", Energy Analysis Department Lawrence Berkeley National Laboratory, September 2011. |
| 9 | 2008, Water Conservation Program: ShowerStart Pilot Project White Paper, City of San Diego, CA. |
| 10 | 2012, Pacific Gas and Electric Company, Work Paper PGECODHW113, Low Flow Showerhead and Thermostatic Shower Restriction Valve, Revision # 4, August 2012. |
| 11 | 2008, "Simply & Cost Effectively Reducing Shower Based Warm-Up Waste: Increasing Convenience & Conservation by Attaching ShowerStart to Existing Showerheads", ShowerStart LLC. |
| 12 | 2014, New York State Record of Revision to the TRM, Case 07-M-0548, June 19, 2014. |

**MEASURE CODE: RS-HWE-TRVA-V04-190101**

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

## 5.4.9 Shower Timer

### Description

Shower Timers are designed to make it easy for people to consistently take short showers, resulting in water and energy savings.

The shower timer provides a reminder to participants on length of their shower visually or auditorily.

This measure was developed to be applicable to the following program type: KITS, DI.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The shower timer should provide a reminder to participants to keep showers to a length of 5 minutes or less.

### Definition of Baseline Equipment

The baseline is no shower timer.

### Deemed Lifetime of Efficient Equipment

The deemed lifetime is 2 years[721].

### Deemed Measure Cost

For shower timers provided in Efficiency Kits, the actual program delivery costs should be utilized.

### Loadshape

Loadshape R03 - Residential Electric DHW

### Coincidence Factor

The coincidence factor for this measure is assumed to be 2.78%.[722]

**Algorithm**

### Calculation of Energy Savings

### Electric Energy Savings

ΔkWh = %Electric DHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Electric

Where:

%Electric DHW = Proportion of water heating supplied by electric resistance heating

[721] Estimate of persistence of behavior change instigated by the shower timer.

[722] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period, where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

| DHW fuel | %ElectricDHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 16%[723] |

GPM = Flow rate of showerhead as used

= Custom, to be determined through evaluation. If data is not available use 1.93[724]

L_base = Number of minutes in shower without a shower timer

=7.8 minutes[725]

L_timer = Number of minutes in shower after shower timer

= Custom, to be determined through evaluation. If data is not available use 5.79[726]

Household = Number in household using timer

| Household Unit Type[727] | Household |
|---|---|
| Single-Family - Deemed | 2.56[728] |
| Multi-Family - Deemed | 2.1[729] |
| Household type unknown | 2.42[730] |
| Custom | Actual Occupancy or Number of Bedrooms[731] |

Days/yr = 365.25

SPCD = Showers Per Capita Per Day

= 0.6[732]

UsageFactor = How often each participant is using shower timer

=Custom, to be determined through evaluation. If data is not available use 0.34[733]

723 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

724 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

725 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and Multifamily homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

726 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

727 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

728 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

729 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

730 Unknown is 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.

731 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

732 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

733 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

EPG_Electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 54.1)) / (0.98 * 3412)

=0.117 kWh/gal

Based on default assumptions provided above, the savings for a single family home would be:

ΔkWh = %Electric DHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Electric

= 0.16 * 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.117

=13.9kWh

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.

$\Delta kWh_{water}$ = ΔWater (gallons) / 1,000,000 * $E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[734]

Based on default assumptions provided above, the savings for a single family home would be:

ΔWater (gallons) = GPM * (L_base – L_timer) * Household ***** Days/yr * SPCD * UsageFactor

= 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34

= 740.0 gallons

$\Delta kWh_{water}$ = 740/1,000,000 * 5010

= 3.7 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) * Household Users * SPCD * 365.25 ) * 0.712 / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

CF = Coincidence Factor for electric load reduction

= 0.0278[735]

[734] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[735] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water

Based on default assumptions provided above, the savings for a single family home would be:

ΔkW = ΔkWh/Hours * CF

= 0.0013 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilDHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas

%FossilDHW = Proportion of water heating supplied by electric resistance heating

| DHW fuel | %FossilDHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[736] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes [737]

= 67% For MF homes[738]

Use Multifamily if: Building has shared DHW.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

Based on default assumptions provided above, the savings for a single family home would be:

Δ Therms = %FossilDHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas

= 0.84 * 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.00501

= 3.1 Therms

in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

[736] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[737] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[738] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

### WATER DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = GPM * (L_base – L_timer) * Household ***** Days/yr * SPCD * UsageFactor

Variables as defined above

Based on default assumptions provided above, the savings for a single family home would be:

ΔWater (gallons) = GPM * (L_base – L_timer) * Household ***** Days/yr * SPCD * UsageFactor

= 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34

= 740.0 gallons

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**MEASURE CODE: RS-DHW-SHTM-V02-190101**

**REVIEW DEADLINE: 1/1/2021**

# 5.5 Lighting End Use

## 5.5.1 Compact Fluorescent Lamp (CFL)

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

### DESCRIPTION

A low wattage qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the CFL is installed in a residential location. If the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used[739].

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) required all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a standard qualified compact fluorescent lamp.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an EISA qualified incandescent or halogen as provided in the table provided in the Electric Energy Savings section.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) for bulbs installed in 2018 is assumed to be 3 years and then for every subsequent year should be reduced by one year[740].

---

[739] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112016.xls'.

[740] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

### DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost is $1.20[741].

For the Direct Install measure, the full cost of $2.45 per bulb should be used, plus $5 labor cost[742] for a total of $7.45 per bulb. However actual program delivery costs should be utilized if available.

For bulbs provided in Efficiency Kits, the actual program delivery costs should be utilized.

### LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

### COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1% for Time of Sale Residential and in-unit Multi Family bulbs, 27.3% for exterior bulbs and 8.1% for unknown[743] and 7.4% for Residential Direct Install[744].

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

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

Where:

WattsBase = Based on lumens of CFL bulb and program year installed:

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|
| 5280 | 6209 | 300 |
| 3000 | 5279 | 200 |
| 2601 | 2999 | 150 |
| 1490 | 2600 | 72 |
| 1050 | 1489 | 53 |
| 750 | 1049 | 43 |
| 310 | 749 | 29 |
| 250 | 309 | 25 |

WattsEE = Actual wattage of CFL purchased / installed

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

---

741 Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

742 Based on 15 minutes at $20 an hour. Includes some portion of travel time to site.

743 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

744 Based on lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation and excluding all logged bulbs installed in closets.

| Program | | Weighted Average 1st Year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|---|
| Retail (Time of Sale) | | 76.5%[745] | 11.6% | 9.9% | 98.0%[746] |
| Direct Install | | 96.9%[747] | | | |
| Efficiency Kits[748] | CFL Distribution[749] | 59% | 13% | 11% | 83% |
| | School Kits[750] | 61% | 13% | 11% | 86% |
| | Direct Mail Kits[751] | 66% | 14% | 12% | 93% |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[752]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation or use deemed assumptions below[753]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

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745 1st year in service rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL RES Lighting ISR_112016.xls' for more information). The average first year ISR for each utility was calculated weighted by the number of bulbs in the each year's survey. This was then weighted by annual sales to give a statewide assumption.

746 The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

747 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.

748 In Service Rates provided are for the CFL bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provided may be used.

749 Free bulbs provided without request, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential CFL Distribution Program', Report Table 11 and Appendix B.

750 Kits provided free to students through school, with education program. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10. Final ISR assumptions are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, and second and third year estimates based on same proportion of future installs.

751 Opt-in program to receive kits via mail, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10, as above.

752 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.

753 Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

| Program Delivery | Installation Location | Hours[754] |
|---|---|---|
| Retail (Time of Sale) and Efficiency Kits | Residential Interior and in-unit Multi Family | 759 |
| | Exterior | 2,475 [755] |
| | Unknown | 847 [756] |
| Direct Install | Residential Interior and in-unit Multi Family | 793 |
| | Exterior | 2,475 |

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

| Bulb Location | WHFe |
|---|---|
| Interior single family or unknown location | 1.06 [757] |
| Multi family in unit | 1.04 [758] |
| Exterior or uncooled location | 1.0 |

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

754 Except where noted, based on lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation. Direct Install value excludes all logged bulbs installed in closets.

755 Based on secondary research conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation.

756 Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.

757 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)

758 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

For example, for a 14W CFL (60W standard incandescent and 43W EISA qualified incandescent/halogen):

$\Delta kWH_{1st\ year\ installs}$ = ((43 - 14) / 1000) * 0.765 * 847 * 1.06

= 19.9 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((43 - 14) / 1000) * 0.116 * 847 * 1.06

= 3.0 kWh

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

$\Delta kWH_{3rd\ year\ installs}$ = ((43 - 14) / 1000) * 0.099 * 847 * 1.06

= 2.6 kWh

**HEATING PENALTY**

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

ΔkWh[759] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49%[760] for interior or unknown location

= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[761]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[762] | N/A | N/A | 1.28 |

For example, a 14W standard CFL is purchased and installed in home with 2.0 COP (including duct loss) Heat Pump:

$\Delta kWh_{1st\ year}$ = - (((43 - 14) / 1000) * 0.765 * 759 * 0.49) / 2.0

= - 4.2 kWh

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

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

760 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.

761 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.

762 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.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1 000) * 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 or unknown location | 1.11[763] |
| Multi family in unit | 1.07[764] |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure.

| Program Delivery | Bulb Location | CF[765] |
|---|---|---|
| Retail(Time of Sale) | Interior single family or Multi Family in unit | 7.1% |
| | Exterior | 27.3% |
| | Unknown location | 8.1% |
| Direct Install | Residential | 7.4% |

Other factors as defined above

For example, a 14W standard CFL is purchased and installed in a single family interior location:

ΔkW = ((43 - 14) / 1000) * 0.765 * 1.11 * 0.071

= 0.0017 kW

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

**NATURAL GAS SAVINGS**

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

ΔTherms[766] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49%[767] for interior or unknown location

= 0% for exterior or unheated location

---

763 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.

764 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

765 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. Direct Install value is based on resut excluding all logged bulbs installed in closets.

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

767 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.

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[768]

For example, a 14 standard CFL is purchased and installed in a home:

ΔTherms = - (((43 - 14) / 1000) * 0.765 * 759 * 0.49 * 0.03412) / 0.7

= - 0.40 Therms

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

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

The O&M assumptions that should be used in cost effectiveness calculations are provided below:

| Program Delivery | Installation Location | Replacement Period (years)[769] | Replacement Cost[770] |
|---|---|---|---|
| Retail (Time of Sale) and Efficiency Kits | Residential Interior and in-unit Multi Family | 1.3 | $1.25 |
| | Exterior | 0.4 | |
| | Unknown | 1.2 | |
| Direct Install | Residential Interior and in-unit Multi Family | 1.3 | |
| | Exterior | 0.4 | |

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs are actually in service and so should be multiplied by the appropriate ISR.

### MEASURE CODE: RS-LTG-ESCF-V08-190101

### REVIEW DEADLINE: 1/1/2020

[768] 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

[769] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

[770] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

## 5.5.2 ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

**DESCRIPTION**

A qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb.

Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the specialty CFL is installed in a residential location. If the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used[771].

This measure was developed to be applicable to the following program types: TOS, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the high-efficiency equipment must be a qualified specialty compact fluorescent lamp.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is a specialty incandescent light bulb including those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (<40W), candelabra base (<60W), vibration service bulb, decorative candle with medium or intermediate base (<40W), shatter resistant and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5" diameter and >40W), candle (shapes B, BA, CA >40W, candelabra base lamps (>60W) and intermediate base lamps (>40W).

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 6.8 year[772] for bulbs exempt from EISA, or 3 years for bulbs non-exempt installed in 2018 and then for every subsequent year should be reduced by one year[773].

[771] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112015.xls'.

[772] The assumed measure life for the specialty bulb measure characterization was reported in "Residential Lighting Measure Life Study", Nexus Market Research, June 4, 2008 (measure life for markdown bulbs). Measure life estimate does not distinguish between equipment life and measure persistence. Measure life includes products that were installed and operated until failure (i.e., equipment life) as well as those that were retired early and permanently removed from service for any reason, be it early failure, breakage, or the respondent not liking the product (i.e., measure persistence).

[773] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

### DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $5[774].

For the Direct Install measure, the full cost of $8.50 should be used plus $5 labor[775] for a total of $13.50. However actual program delivery costs should be utilized if available.

For bulbs provided in Efficiency Kits, the actual program delivery costs should be utilized.

### LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

### COINCIDENCE FACTOR

Unlike standard CFLs that could be installed in any room, certain types of specialty CFLs are more likely to be found in specific rooms, which affects the coincident peak factor. Coincidence factors by bulb types are presented below[776]

| Bulb Type | Peak CF |
|---|---|
| Three-way | 0.078[777] |
| Dimmable | 0.078[778] |
| Interior reflector (incl. dimmable) | 0.091 |
| Exterior reflector | 0.273 |
| Candelabra base and candle medium and intermediate base | 0.121 |
| Bug light | 0.273 |
| Post light (>100W) | 0.273 |
| Daylight | 0.081 |
| Plant light | 0.081 |
| Globe | 0.075 |
| Vibration or shatterproof | 0.081 |
| Standard spirals >= 2601 lumens, Residential, Multi-family in unit | 0.071 |
| Standard spirals >= 2601 lumens, unknown | 0.081 |
| Standard spirals >= 2601 lumens, exterior | 0.273 |
| Specialty - Generic | 0.081 |

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

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

Where:

WattsBase = Actual wattage equivalent of incandescent specialty bulb, use the tables below to obtain

[774] NEEP Residential Lighting Survey, 2011

[775] Based on 15 minutes at $20 per hour.

[776] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[777] Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[778] Ibid

the incandescent bulb equivalent wattage[779]; use 60W if unknown[780]

EISA exempt bulb types:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | WattsBase |
|---|---|---|---|
| **Standard Spirals >=2601** | 2601 | 2999 | 150 |
| | 3000 | 5279 | 200 |
| | 5280 | 6209 | 300 |
| **3-Way** | 250 | 449 | 25 |
| | 450 | 799 | 40 |
| | 800 | 1099 | 60 |
| | 1100 | 1599 | 75 |
| | 1600 | 1999 | 100 |
| | 2000 | 2549 | 125 |
| | 2550 | 2999 | 150 |
| **Globe (medium and intermediate bases less than 750 lumens)** | 90 | 179 | 10 |
| | 180 | 249 | 15 |
| | 250 | 349 | 25 |
| | 350 | 749 | 40 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)** | 70 | 89 | 10 |
| | 90 | 149 | 15 |
| | 150 | 299 | 25 |
| | 300 | 749 | 40 |
| **Globe (candelabra bases less than 1050 lumens)** | 90 | 179 | 10 |
| | 180 | 249 | 15 |
| | 250 | 349 | 25 |
| | 350 | 499 | 40 |
| | 500 | 1049 | 60 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)** | 70 | 89 | 10 |
| | 90 | 149 | 15 |
| | 150 | 299 | 25 |
| | 300 | 499 | 40 |
| | 500 | 1049 | 60 |

**Directional Lamps -** ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for lamps with rated wattages less than 20Wand 50 Lm/W for lamps with rated wattages >= 20 watts[781].

For Directional R, BR, and ER lamp types[782]:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | $Watts_{Base}$ |
|---|---|---|---|
| **R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)** | 420 | 472 | 40 |
| | 473 | 524 | 45 |
| | 525 | 714 | 50 |

[779] Based upon the ENERGY STAR specification for lamps and the Energy Policy and Conservation Act of 2012.
[780] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)
[781] From pg 10 of the Energy Star Specification for lamps v1.1
[782] From pg 11 of the Energy Star Specification for lamps v1.1

| Bulb Type | Lower Lumen Range | Upper Lumen Range | $Watts_{Base}$ |
|---|---|---|---|
| | 715 | 937 | 65 |
| | 938 | 1259 | 75 |
| | 1260 | 1399 | 90 |
| | 1400 | 1739 | 100 |
| | 1740 | 2174 | 120 |
| | 2175 | 2624 | 150 |
| | 2625 | 2999 | 175 |
| | 3000 | 4500 | 200 |
| ***R, BR, and ER with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| | 650 | 1199 | 65 |
| ***ER30, BR30, BR40, or ER40** | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| ***BR30, BR40, or ER40** | 650 | 1419 | 65 |
| ***R20** | 400 | 449 | 40 |
| | 450 | 719 | 45 |
| ***All reflector lamps below lumen ranges specified above** | 200 | 299 | 20 |
| | 300 | 399 | 30 |

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[783] If CBCP and beam angle information are not available, or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[784]

$$\text{Wattsbase} =$$

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

| Diameter | Permitted Wattages |
|---|---|
| 16 | 20, 35, 40, 45, 50, 60, 75 |
| 20 | 50 |
| 30S | 40, 45, 50, 60, 75 |
| 30L | 50, 75 |

[783] See 'ESLampCenterBeamTool.xls'.

[784] The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

| Diameter | Permitted Wattages |
|---|---|
| 38 | 40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250 |

EISA non-exempt bulb types:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|---|
| **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 29 |
| | 750 | 1049 | 43 |
| | 1050 | 1489 | 53 |
| | 1490 | 2600 | 72 |

WattsEE = Actual wattage of energy efficient specialty bulb purchased, use 15W if unknown[785]

ISR = In Service Rate, the percentage of units 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 |
|---|---|---|---|---|---|
| Retail (Time of Sale) | | 88.0%[786] | 5.4% | 4.6% | 98.0%[787] |
| Direct Install | | 96.9%[788] | | | |
| Efficiency Kits[789] | CFL Distribution[790] | 59% | 13% | 11% | 83% |
| | School Kits[791] | 61% | 13% | 11% | 86% |
| | Direct Mail | 66% | 14% | 12% | 93% |

785 An evaluation (Energy Efficiency / Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: Residential Energy Star ® Lighting ) reported 13-17W as the most common specialty CFL wattage (69% of program bulbs). 2009 California data also reported an average CFL wattage of 15.5 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program, Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009).

786 1st year in service rate is based upon review of PY4-6 evaluations from ComEd and PY5-6 from Ameren (see 'IL RES Lighting ISR_122014.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.

787 The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

788 Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

789 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.

790 Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

791 Kits provided free to students through school, with education program. Consistent with Standard CFL assumptions.

| Program | | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|---|
| | Kits[792] | | | | |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[793]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[794]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year, varies by bulb type as presented below:[795]

| Bulb Type | Annual hours of use (HOU) |
|---|---|
| Three-way | 850 |
| Dimmable | 850 |
| Interior reflector (incl. dimmable) | 861 |
| Exterior reflector | 2475 |
| Candelabra base and candle medium and intermediate base | 1190 |
| Bug light | 2475 |
| Post light (>100W) | 2475 |
| Daylight | 847 |
| Plant light | 847 |
| Globe | 639 |
| Vibration or shatterproof | 847 |
| Standard Spiral >2601 lumens, Residential, Multi Family in-unit | 759 |
| Standard Spiral >2601 lumens, unknown | 847 |
| Standard Spiral >2601 lumens, Exterior | 2475 |
| Specialty - Generic | 847 |

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

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792 Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

793 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.

794 Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

795 Hours of use by specialty bulb type calculated using the average hours of use in locations or rooms where each type of specialty bulb is most commonly found. Values for Reflector, Decorative and Globe are taken directly from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. All other hours have been updated based on the room specific hours of use from the PY5/PY6 logger study.

| Bulb Location | WHFe |
|---|---|
| Interior single family or unknown location | 1.06 [796] |
| Multi family in unit | 1.04 [797] |
| Exterior or uncooled location | 1.0 |

## DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

For example, for a 13W dimmable CFL impacted by EISA 2007 (60W standard incandescent and 43W EISA qualified incandescent/halogen).

$\Delta kWH_{1st\ year\ installs}$ = ((60 - 13) / 1000) * 0.823 * 850 * 1.06

= 34.9 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((43 - 13) / 1000) * 0.085 * 850 * 1.06

= 2.3 kWh

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

$\Delta kWH_{3rd\ year\ installs}$ = ((43 - 13) / 1000) * 0.072 * 850 * 1.06

= 1.9 kWh

Note: delta watts is equivalent to install year. Here we assume no change in hours assumption.

## HEATING PENALTY

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

ΔkWh[798] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49%[799] for interior or unknown location

[796] 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)

[797] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).

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

[799] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate

= 0% for exterior location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[800]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[801] | N/A | N/A | 1.28 |

For example, a 15W globe CFL replacing a 60W incandescent specialty bulb installed in home with 2.0 COP Heat Pump (including duct loss):

$\Delta kWh_{1st\ year}$ = - (((60 - 15) / 1000) * 0.823 * 639 * 0.49) / 2.0

= - 5.8 kWh

Second and third year savings should be calculated using the appropriate ISR.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW =((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 or unknown location | 1.11[802] |
| Multi family in unit | 1.07[803] |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure. Coincidence factors by bulb types are presented below[804]

modeling of several different configurations and IL locations of homes.

[800] 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.

[801] 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.

[802] 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.

[803] 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).

[804] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

| Bulb Type | Peak CF |
|---|---|
| Three-way | 0.078[805] |
| Dimmable | 0.078[806] |
| Interior reflector (incl. dimmable) | 0.091 |
| Exterior reflector | 0.273 |
| Candelabra base and candle medium and intermediate base | 0.121 |
| Bug light | 0.273 |
| Post light (>100W) | 0.273 |
| Daylight | 0.081 |
| Plant light | 0.081 |
| Globe | 0.075 |
| Vibration or shatterproof | 0.081 |
| Standard Spiral >=2601 lumens, Residential, Multi-family in unit | 0.071 |
| Standard spirals >= 2601 lumens, unknown | 0.081 |
| Standard spirals >= 2601 lumens, exterior | 0.273 |
| Specialty - Generic | 0.081 |

Other factors as defined above

For example, a 15W specialty CFL replacing a 60W incandescent specialty bulb:

$\Delta kW_{1st\ year}$ = ((60 - 15) / 1000) * 0.823 * 1.11 * 0.081

= 0.003 kW

Second and third year savings should be calculated using the appropriate ISR.

**NATURAL GAS SAVINGS**

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

ΔTherms[807] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49%[808] for interior or unknown location

= 0% for exterior location

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[809]

805 Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

806 Ibid

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

808 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.

809 This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.)
In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy

For example, a 15W Globe specialty CFL replacing a 60W incandescent specialty bulb:

ΔTherms = - (((60 - 15) / 1000) * 0. 823 * 639 * 0.49 * 0.03412) / 0.7

= - 0.57 Therms

Second and third year savings should be calculated using the appropriate ISR.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The following O&M assumptions should be used: Life of the baseline bulb is assumed to be 1.32 year[810]; baseline replacement cost is assumed to be $3.5[811].

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-ESCC-V07-190101**

**REVIEW DEADLINE: 1/1/2020**

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

[810] Assuming 1000 hour rated life for incandescent bulb: 1000/759 = 1.32

[811] NEEP Residential Lighting Survey, 2011

## 5.5.3 ENERGY STAR Torchiere

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

### DESCRIPTION

A high efficiency ENERGY STAR fluorescent torchiere is purchased in place of a baseline mix of halogen and incandescent torchieres and installed in a residential setting.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the fluorescent torchiere must meet ENERGY STAR efficiency standards.

### DEFINITION OF BASELINE EQUIPMENT

The baseline is based on a mix of halogen and incandescent torchieres.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of the measure is assumed to be 8 years[812].

### DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $5[813].

### LOADSHAPE

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

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is 7.1% for Residential and in-unit Multi Family bulbs and 8.1% for bulbs installed in unknown locations[814].

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((\Delta Watts) / 1000) * ISR * (1\text{-}Leakage) * HOURS * WHFe$$

Where:

ΔWatts = Average delta watts per purchased ENERGY STAR torchiere

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[812] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[813] DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com) and consistent with Efficiency Vermont TRM.
[814] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

= 115.8 [815]

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

= 0.86 [816]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[817]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[818]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

HOURS = Average hours of use per year

| Installation Location | Hours |
|---|---|
| Residential and in-unit Multi Family | 1095 (3.0 hrs per day)[819] |

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

| Bulb Location | WHFe |
|---|---|
| Interior single family or unknown location | 1.06 [820] |
| Multi family in unit | 1.04 [821] |
| Exterior or uncooled location | 1.0 |

For single family buildings:

ΔkWh = (115.8 /1000) * 0.86 * 1095 * 1.06

[815] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 43 (Table 4-9)

[816] Nexus Market Research, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs" table 6-3 on p63 indicates that 86% torchieres were installed in year one.

[817] 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.

[818] Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

[819] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 104 (Table 9-7)

[820] 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)

[821] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

= 116 kWh

For multi family in unit:

ΔkWh = (115.8 /1000) * 0.86 * 1095 * 1.04

= 113 kWh

**HEATING PENALTY**

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

ΔkWh[822] = - ((ΔWatts) /1000) * ISR * (1-Leakage) * HOURS * HF) / ηHeat

Where:

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

= 49%[823] for interior or unknown location

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use defaults provided below[824]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[825] | N/A | N/A | 1.28 |

For example, an ES torchiere installed in a house with a 2016 heat pump:

ΔkWh = - ((115.8) / 1000) * 0.86 * 1095 * 0.49) / 2.04

= - 26.2 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((ΔWatts) /1000) * ISR * (1-Leakage) * WHFd * CF

Where:

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

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

823 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.

824 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.

825 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.

| Bulb Location | WHFd |
|---|---|
| Interior single family or unknown location | 1.11[826] |
| Multi family in unit | 1.07[827] |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure

| Bulb Location | CF[828] |
|---|---|
| Interior single family or Multi family in unit | 7.1% |
| Unknown location | 8.1% |

For single family and multi-family in unit buildings:

ΔkW = (115.8 / 1000) * 0.86 * 1.11 * 0.071

= 0.008kW

For unknown location:

ΔkW = (115.8 / 1000) * 0.86 * 1.07 * 0.081

= 0.009 kW

**NATURAL GAS SAVINGS**

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

$\Delta Therms_{WH}$ = - (((ΔWatts) /1000) * ISR * (1-Leakage) * HOURS * 0.03412 * HF) / ηHeat

Where:

$\Delta Therms_{WH}$ = gross customer annual heating fuel increased usage for the measure from the reduction in lighting heat in therms.

0.03412 = conversion from kWh to therms

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

= 49% [829]

ηHeat = average heating system efficiency

= 70% [830]

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[826] 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.

[827] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[828] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[829] 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.

[830] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

$\Delta Therms_{WH}$ = - ((115.8 / 1000) * 0.86 * 1095 * 0.03412 * 0.49) / 0.70

= - 2.60 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Life of the baseline bulb is assumed to be 1.83 years[831] for residential and multifamily in unit. Baseline bulb cost replacement is assumed to be $6.[832]

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.

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

[831] Based on VEIC assumption of baseline bulb (mix of incandescent and halogen) average rated life of 2000 hours, 2000/1095 = 1.83 years.

[832] Derived from Efficiency Vermont TRM.

## 5.5.4 Exterior Hardwired Compact Fluorescent Lamp (CFL) Fixture

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

### DESCRIPTION

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an exterior residential setting. This measure could relate to either a fixture replacement or new installation (i.e. time of sale).

Federal legislation stemming from the Energy Independence and Security Act of 2007 required all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ends in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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

### DEFINITION OF EFFICIENT EQUIPMENT

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

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard EISA qualified incandescent or halogen exterior fixture as provided in the table provided in the Electric Energy Savings section.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected life of an exterior fixture is 20 years[833]. However due to the backstop provision in the Energy Independence and Security Act of 2007 that requires by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, the baseline replacement would become a CFL in that year. The expected measure life for CFL fixtures installed in 2018 is therefore assumed to be 3 years. For bulbs installed in 2019, this would be reduced to 2 years[834].

### DEEMED MEASURE COST

The incremental cost for an exterior fixture is assumed to be $32[835].

### LOADSHAPE

Loadshape R07 - Residential Outdoor Lighting

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833 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 gives 20 years for an interior fluorescent fixture.

834 Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

835 ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for exterior fixture.

### Coincidence Factor

The summer peak coincidence factor is assumed to be 27.3%[836].

## Algorithm

### Calculation of Savings

### Electric Energy Savings

ΔkWh =((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours

Where:

WattsBase = Based on lumens of CFL bulb and program year purchased:

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|
| 5280 | 6209 | 300 |
| 3000 | 5279 | 200 |
| 2601 | 2999 | 150 |
| 1490 | 2600 | 72 |
| 1050 | 1489 | 53 |
| 750 | 1049 | 43 |
| 310 | 749 | 29 |
| 250 | 309 | 25 |

WattsEE = Actual wattage of CFL purchased

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

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| Retail (Time of Sale) | 87.5%[837] | 5.7% | 4.8% | 98.0%[838] |
| Direct Install | 96.9[839] | | | |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if

[836] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[837] 1st year in service rate is based upon review of PY2-3 evaluations from ComEd (see 'IL RES Lighting ISR.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.

[838] The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[839] In the absence of evaluation results for Direct Install Fixtures specifically, this is made consistent with the Direct Install CFL measure which is based upon review of the PY2 and PY3 ComEd Direct Install program surveys.

deemed appropriate[840]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[841]:

ComEd: 1.05%

Ameren: 6.55%

All other programs = 0

Hours = Average hours of use per year

=2475 (6.78 hrs per day)[842]

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

For example, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen).

$\Delta kWH_{1st\ year\ installs}$ = ((86 - 28) / 1000) * 0.875 * 2475

= 125.6 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((86 - 28) / 1000) * 0.057 * 2475

= 8.2 kWh

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

$\Delta kWH_{3rd\ year\ installs}$ = ((86 - 28) / 1000) * 0.048 * 2475

= 6.9 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * (1-Leakage) * CF

Where:

CF = Summer Peak Coincidence Factor for measure.

[840] 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.

[841] Leakage rate is based upon TAC agreed 50% of the lamp leakage assumptions (based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information)).

[842] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

= 27.3%[843]

Other factors as defined above

For example, a 2 x 14W pin-based CFL fixture:

$\Delta kW_{1st\ year}$ = ((86 - 28) / 1000) * 0.875 * 0.273

= 0.0142 kW

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

### NATURAL GAS SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

Life of the baseline bulb is assumed to be 0.4 years[844] for exterior applications. Baseline bulb cost replacement is assumed to be $1.25.[845]

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.

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### REVIEW DEADLINE: 1/1/2020

[843] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
[844] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).
[845] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

## 5.5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

### DESCRIPTION

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an interior residential setting. This measure could relate to either a fixture replacement or new installation (i.e. time of sale).

Federal legislation stemming from the Energy Independence and Security Act of 2007 required all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ends in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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

### DEFINITION OF EFFICIENT EQUIPMENT

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

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard EISA qualified incandescent or halogen interior fixture as provided in the table provided in the Electric Energy Savings section.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected life of an interior fixture is 20 years[846]. However due to the backstop provision in the Energy Independence and Security Act of 2007 that requires by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, the baseline replacement would become equivalent to a CFL in that year. The expected measure life for CFL fixtures installed in 2018 is therefore assumed to be 3 years. For bulbs installed in 2019, this would be reduced to 2 years and should be reduced each year[847].

### DEEMED MEASURE COST

The incremental cost for an interior fixture is assumed to be $32[848].

### LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

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846 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 gives 20 years for an interior fluorescent fixture.

847 Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

848 ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture.

### COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1%[849] for Residential and in-unit Multi Family bulbs.

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

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

Where:

WattsBase = Based on lumens of CFL bulb and program year purchased:

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 ($Watts_{Base}$) |
|---|---|---|
| 5280 | 6209 | 300 |
| 3000 | 5279 | 200 |
| 2601 | 2999 | 150 |
| 1490 | 2600 | 72 |
| 1050 | 1489 | 53 |
| 750 | 1049 | 43 |
| 310 | 749 | 29 |
| 250 | 309 | 25 |

WattsEE = Actual wattage of CFL purchased

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

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| Retail (Time of Sale) | 87.5%[850] | 5.7% | 4.8% | 98.0%[851] |
| Direct Install | 96.9[852] | | | |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if

[849] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[850] 1st year in service rate is based upon review of PY2-3 evaluations from ComEd (see 'IL RES Lighting ISR.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.

[851] The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[852] In the absence of evaluation results for Direct Install Fixtures specifically, this is made consistent with the Direct Install CFL measure which is based upon review of the PY2 and PY3 ComEd Direct Install program surveys.

deemed appropriate[853]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[854]:

ComEd: 1.05%

Ameren: 6.55%

All other programs = 0

Hours = Average hours of use per year

| Installation Location | Hours |
|---|---|
| Residential and in-unit Multi Family | 759 [855] |

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

| Bulb Location | WHFe |
|---|---|
| Interior single family or unknown location | 1.06 [856] |
| Multi family in unit | 1.04 [857] |

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

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[853] 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.

[854] Leakage rate is based upon TAC agreed 50% of the lamp leakage assumptions (based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information)).

[855] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[856] 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)

[857] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

For example, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen):

$\Delta kWH_{1st\ year\ installs}$ = ((86 - 28) / 1000) * 0.875 * 759 * 1.06

= 40.8 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((86 - 28) / 1000) * 0.057 * 759 * 1.06

= 2.7 kWh

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

$\Delta kWH_{3rd\ year\ installs}$ = ((86 - 28) / 1000) * 0.048 * 759 * 1.06

= 2.2 kWh

**HEATING PENALTY**

If electric heated building:

ΔkWh[858] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49%[859] for interior or unknown location

= 0% for unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[860]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[861] | N/A | N/A | 1.28 |

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

859 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.

860 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.

861 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

For example, a 2 x 14W pin-based CFL fixture is purchased and installed in home with 2.0 COP (including duct loss) Heat Pump:

$\Delta kWh_{1st\ year}$ = - (((86 – 28) / 1000) * 0.875 * 759 * 0.49) / 2.0

= - 9.4 kWh

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

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * 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 or unknown location | 1.11[862] |
| Multi family in unit | 1.07[863] |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure.

| Bulb Location | CF[864] |
|---|---|
| Interior single family or unknown location | 7.1% |
| Multi family in unit | 7.1% |

Other factors as defined above

For example, a 14W pin-based CFL fixture:

$\Delta kW_{1st\ year}$ = ((86- 28) / 1000) * 0.875 * 1.11 * 0.071

= 0.004 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

ΔTherms[865] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49%[866] for interior or unknown location

[862] 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.

[863] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[864] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

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

[866] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate

= 0% for unheated location

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[867]

For example, a 2 x 14W pin-based CFL fixture is purchased and installed in home with gas heat at 70% efficiency:

$\Delta Therms_{1st\ year}$ = -((86 - 28) / 1000) * 0.875 * 759 * 0.49 * 0.03412) / 0.7

= - 0.9 Therms

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

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

Life of the baseline bulb is assumed to be 1.3 years[868] for interior applications. Baseline bulb cost replacement is assumed to be $1.25.[869]

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

## MEASURE CODE: RS-LTG-IFIX-V08-190101

## REVIEW DEADLINE: 1/1/2020

modeling of several different configurations and IL locations of homes.

867 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

868 Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

869 Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

## 5.5.6 LED Specialty Lamps

### Description

This measure describes savings from a variety of specialty LED lamp types (including globe, decorative and downlights). This characterization assumes that the LED lamp is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used[870].

This measure was developed to be applicable to the following program types: TOS, NC, EREP, KITS.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be an ENERGY STAR LED lamp or fixture. Note a new ENERGY STAR specification v2.1 becomes effective on 1/2/2017.

### Definition of Baseline Equipment

Specialty and Directional lamps were not included in the original definition of General Service Lamps in the Energy Independence and Security Act of 2007 (EISA). Therefore, the initial baseline is an incandescent / halogen lamp described in the table below.

However, a DOE Final Rule released on 1/19/2017 updated the EISA regulations to remove the exemption for these lamp types such that they become subject to the backstop provision defined within the original legislation. The backstop provision requires that by January 1, 2020, all lamps sold must meet efficiency criteria of at least 45 lumens per watt. Since baseline lamps have significantly lower rated lifetimes, this requires that a baseline shift reducing the annual savings is incorporated during the lifetime of the measure.

There is however, uncertainty around the final application of the EISA backstop provision, particularly whether the expanded definition will hold, as well as uncertainty regarding how the market for these products would change absent the backstop. Therefore the 2019 version of this measure delays application of the midlife adjustment associated with the backstop provision to 1/1/2024. However, TAC members commit to making appropriate mid-year adjustments to the measure characterization in the event that new information adds sufficient clarity and concludes any legal challenges to support making a change to this agreement. This means that if within PY2019, it becomes clear that the EISA backstop *will* apply to the measures characterized herein, the timing of the midlife adjustment will be changed to be applied in 2021, consistent with the omnidirectional measure. Likewise, if it becomes clear that these lamp types will revert to being exempt, the midlife adjustment will be removed. In addition, the TAC and IL TRM Administrator must consider NTG and lifetime assumptions and if consensus is reached apply coordinated adjustments to the TRM at that time (if consensus is not reached the most recent NTG evaluation results for these measures will be applied). Any mid-year adjustments to the TRM and NTG would be applied for all installs beginning 30 days after agreement is reached, rather than waiting for the next TRM update.

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

### Deemed Lifetime of Efficient Equipment

The deemed measure life is 6.1 years[871] for exterior applications. For all other applications, lifetimes are capped at 10 years[872].

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[870] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 in store intercept survey results. See 'RESvCI Split_2018.xlsx'.
[871] ENERGY STAR v2.1 requires all LED bulbs to be rated for at least 15,000 hours. 15000/2475 (exterior hours of use) = 6.1 years.
[872] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFLs, the remaining life is 3,333 hours[873].

**DEEMED MEASURE COST**

The price of LED lamps is falling quickly. Where possible, the actual cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following[874]:

| Bulb Type | Year | Incandescent | LED | Incremental Cost |
|---|---|---|---|---|
| Directional | 2019 and on | $3.53 | $5.18 | $1.65 |
| Decorative and Globe | 2019 and on | $1.74 | $3.40 | $1.66 |

**LOADSHAPE**

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor is assumed to be 0.109 for residential and in-unit multifamily bulbs[875], 0.273 for exterior bulbs[876] and 0.117 for unknown[877].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:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the table below for default values.[878]

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below.

[873] Representing a third of the expected lamp lifetime.
[874] Baseline and LED lamp costs for both directional and decorative and globe are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis. .
[875] 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.
[876] 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 specialty LEDs in exterior applications.
[877] 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.
[878] See file "LED baseline and EE wattage table_2018.xlsx" for details on lamp wattage calculations.

**Decorative Lamps – ENERGY STAR Minimum Luminous Efficacy = 65Lm/W for all lamps**

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$) [879] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| 3-Way | 250 | 449 | 350 | 4.4 | 25 | 20.6 | 7.8 | 3.3 |
| | 450 | 799 | 625 | 7.9 | 40 | 32.1 | 13.9 | 6.0 |
| | 800 | 1,099 | 950 | 12.1 | 60 | 47.9 | 21.1 | 9.0 |
| | 1,100 | 1,599 | 1350 | 17.1 | 75 | 57.9 | 30.0 | 12.9 |
| | 1,600 | 1,999 | 1800 | 22.8 | 100 | 77.2 | 40.0 | 17.1 |
| | 2,000 | 2,549 | 2275 | 28.9 | 125 | 96.1 | 50.5 | 21.7 |
| | 2,550 | 2,999 | 2775 | 35.2 | 150 | 114.8 | 61.7 | 26.4 |
| Globe (medium and intermediate bases less than 750 lumens) | 90 | 179 | 135 | 2.1 | 10 | 7.9 | 3.0 | 0.9 |
| | 180 | 249 | 215 | 3.3 | 15 | 11.7 | 4.8 | 1.5 |
| | 250 | 349 | 300 | 4.6 | 25 | 20.4 | 6.7 | 2.0 |
| | 350 | 749 | 550 | 8.5 | 40 | 31.5 | 12.2 | 3.8 |
| Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens) | 70 | 89 | 80 | 1.2 | 10 | 8.8 | 1.8 | 0.5 |
| | 90 | 149 | 120 | 1.8 | 15 | 13.2 | 2.7 | 0.8 |
| | 150 | 299 | 225 | 3.5 | 25 | 21.5 | 5.0 | 1.5 |
| | 300 | 749 | 525 | 8.1 | 40 | 31.9 | 11.7 | 3.6 |
| Globe (candelabra bases less than 1050 lumens) | 90 | 179 | 135 | 2.1 | 10 | 7.9 | 3.0 | 0.9 |
| | 180 | 249 | 215 | 3.3 | 15 | 11.7 | 4.8 | 1.5 |
| | 250 | 349 | 300 | 4.6 | 25 | 20.4 | 6.7 | 2.0 |
| | 350 | 499 | 425 | 6.5 | 40 | 33.5 | 9.4 | 2.9 |
| | 500 | 1,049 | 775 | 11.9 | 60 | 48.1 | 17.2 | 5.3 |
| Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens) | 70 | 89 | 80 | 1.2 | 10 | 8.8 | 1.8 | 0.5 |
| | 90 | 149 | 120 | 1.8 | 15 | 13.2 | 2.7 | 0.8 |
| | 150 | 299 | 225 | 3.5 | 25 | 21.5 | 5.0 | 1.5 |
| | 300 | 499 | 400 | 6.1 | 40 | 33.9 | 8.9 | 2.7 |
| | 500 | 1,049 | 775 | 11.9 | 60 | 48.1 | 17.2 | 5.3 |

**Directional Lamps -** ENERGY STAR Minimum Luminous Efficacy = 70Lm/W for <90 CRI lamps and 61 Lm/W for >=90CRI lamps.

For Directional R, BR, and ER lamp types[880]:

[879] Calculated as 45lm/W for all EISA non-exempt bulbs

[880] From pg 13 of the ENERGY STAR Specification for lamps v2.1

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$) [881] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below) | 420 | 472 | 446 | 6.6 | 40 | 33.4 | 9.9 | 3.4 |
| | 473 | 524 | 499 | 7.3 | 45 | 37.7 | 11.1 | 3.8 |
| | 525 | 714 | 620 | 9.1 | 50 | 40.9 | 13.8 | 4.7 |
| | 715 | 937 | 826 | 12.1 | 65 | 52.9 | 18.4 | 6.2 |
| | 938 | 1259 | 1099 | 16.2 | 75 | 58.8 | 24.4 | 8.3 |
| | 1260 | 1399 | 1330 | 19.6 | 90 | 70.4 | 29.6 | 10.0 |
| | 1400 | 1739 | 1570 | 23.1 | 100 | 76.9 | 34.9 | 11.8 |
| | 1740 | 2174 | 1957 | 28.8 | 120 | 91.2 | 43.5 | 14.7 |
| | 2175 | 2624 | 2400 | 35.3 | 150 | 114.7 | 53.3 | 18.0 |
| | 2625 | 2999 | 2812 | 41.3 | 175 | 133.7 | 62.5 | 21.1 |
| | 3000 | 4500 | 3750 | 55.1 | 200 | 144.9 | 83.3 | 28.2 |
| *R, BR, and ER with medium screw bases w/ diameter <=2.25" | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 499 | 475 | 7.0 | 45 | 38.0 | 10.6 | 3.6 |
| | 500 | 649 | 575 | 8.5 | 50 | 41.5 | 12.8 | 4.3 |
| | 650 | 1199 | 925 | 13.6 | 65 | 51.4 | 20.6 | 7.0 |
| *ER30, BR30, BR40, or ER40 | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 499 | 475 | 7.0 | 45 | 38.0 | 10.6 | 3.6 |
| | 500 | 649 | 575 | 8.5 | 50 | 41.5 | 12.8 | 4.3 |
| *BR30, BR40, or ER40 | 650 | 1419 | 1035 | 15.2 | 65 | 49.8 | 23.0 | 7.8 |
| *R20 | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 719 | 585 | 8.6 | 45 | 36.4 | 13.0 | 4.4 |
| *All reflector lamps below lumen ranges specified above | 200 | 299 | 250 | 3.7 | 20 | 16.3 | 5.6 | 1.9 |
| | 300 | 399 | 350 | 5.1 | 30 | 24.9 | 7.8 | 2.6 |

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the ENERGY STAR Center Beam Candle Power tool.[882] If CBCP and beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[883]

$$\text{Wattsbase} =$$

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

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[881] Calculated as 45lm/W for all EISA non-exempt bulbs

[882] See 'ESLampCenterBeamTool.xls'.

[883] The ENERGY STAR Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by ENERGY STAR:

| Diameter | Permitted Wattages |
|---|---|
| 16 | 20, 35, 40, 45, 50, 60, 75 |
| 20 | 50 |
| 30S | 40, 45, 50, 60, 75 |
| 30L | 50, 75 |
| 38 | 40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250 |

Additional EISA non-exempt bulb types:

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$)[884] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 530 | 6.7 | 29 | 22.3 | 11.8 | 5.0 |
| | 750 | 1049 | 900 | 11.4 | 43 | 31.6 | 20.0 | 8.6 |
| | 1050 | 1489 | 1270 | 16.1 | 53 | 36.9 | 28.2 | 12.1 |
| | 1490 | 2600 | 2045 | 26.0 | 72 | 46.0 | 45.4 | 19.5 |

ISR = In Service Rate or the percentage of lamps rebated that get installed

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| Retail (Time of Sale) | 84.0%[885] | 7.6% | 6.4% | 98.0%[886] |
| Direct Install | 96.9%[887] | | | |

[884] Calculated as 45lm/W for all EISA non-exempt bulbs

[885] 1st year in service rate is based upon analysis of ComEd PY7, PY8, and PY9 intercept data (see 'Res Lighting ISR_2018.xlsx' for more information).

[886] The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[887] Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| School Kits | 60%[888] | 13% | 11% | 84% |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[889]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below[890]:

ComEd: 2.0%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

| Installation Location | Annual hours of use (HOU) |
|---|---|
| Residential and In-Unit Multi Family | 763[891] |
| Exterior | 2,475[892] |
| Unknown | 1,020[893] |

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

| Bulb Location | WHFe |
|---|---|
| Interior single family | 1.06 [894] |

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.

888 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

889 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.

890 Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY5,6 and 8 for Ameren (see for more information).

891 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.

892 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 specialty LEDs in exterior applications.

893 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.

894 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)

| Bulb Location | WHFe |
|---|---|
| Multifamily in unit | 1.04 [895] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.046[896] |

Use Multifamily if: Building meets utility's definition for multifamily

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location:

ΔkWh = ((45 - 13) / 1000) * 0.840 * (1 – 0.02) * 763 * 1.06

= 21.3 kWh

**Mid Life Baseline Adjustment**

An appropriate baseline adjustment should be included to account for the 2020 EISA backstop provision making replacement baseline lamps meet 45 lumens/watt. Due to uncertainty around the final application of the EISA backstop provision, particularly whether the expanded definition will hold, as well as uncertainty regarding how the market for these products would change absent the backstop, the 2019 version of this measure delays application of the midlife adjustment associated with the backstop provision to 1/1/2024.

Note for early replacement measures an additional baseline shift accounting for the replacement of the existing unit with a new baseline lamp should be accounted for.

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage ($Watts_{EE}$) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 01/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| Decorative EISA 2014 Exempt, 2020 Non-Exempt | 3-Way[897] | 250 | 449 | 4.4 | 20.6 | 3.3 | 16.2% |
| | | 450 | 799 | 7.9 | 32.1 | 6.0 | 18.6% |
| | | 800 | 1,099 | 12.1 | 47.9 | 9.0 | 18.9% |
| | | 1,100 | 1,599 | 17.1 | 57.9 | 12.9 | 22.2% |
| | | 1,600 | 1,999 | 22.8 | 77.2 | 17.1 | 22.2% |
| | | 2,000 | 2,549 | 28.9 | 96.1 | 21.7 | 22.5% |
| | | 2,550 | 2,999 | 35.2 | 114.8 | 26.4 | 23.0% |
| | Globe (medium and intermediate bases less than 750 lumens) | 90 | 179 | 2.1 | 7.9 | 0.9 | 11.6% |
| | | 180 | 249 | 3.3 | 11.7 | 1.5 | 12.5% |
| | | 250 | 349 | 4.6 | 20.4 | 2.0 | 10.0% |
| | | 350 | 749 | 8.5 | 31.5 | 3.8 | 11.9% |
| | Decorative (Shapes B, BA, C, CA, | 70 | 89 | 1.2 | 8.8 | 0.5 | 6.2% |
| | | 90 | 149 | 1.8 | 13.2 | 0.8 | 6.2% |

[895] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[896] Unknown is weighted average of interior v exterior (assuming 15% exterior specialty 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.

[897] For 3-way bulbs or fixtures, the product's median lumens value will be used to determine both LED and baseline wattages.

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage (WattsEE) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 01/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| | **DC, F, G, medium and intermediate bases less than 750 lumens)** | 150 | 299 | 3.5 | 21.5 | 1.5 | 7.1% |
| | | 300 | 749 | 8.1 | 31.9 | 3.6 | 11.2% |
| | **Globe (candelabra bases less than 1050 lumens)** | 90 | 179 | 2.1 | 7.9 | 0.9 | 11.6% |
| | | 180 | 249 | 3.3 | 11.7 | 1.5 | 12.5% |
| | | 250 | 349 | 4.6 | 20.4 | 2.0 | 10.0% |
| | | 350 | 499 | 6.5 | 33.5 | 2.9 | 8.7% |
| | | 500 | 1,049 | 11.9 | 48.1 | 5.3 | 11.0% |
| | **Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)** | 70 | 89 | 1.2 | 8.8 | 0.5 | 6.2% |
| | | 90 | 149 | 1.8 | 13.2 | 0.8 | 6.2% |
| | | 150 | 299 | 3.5 | 21.5 | 1.5 | 7.1% |
| | | 300 | 499 | 6.1 | 33.9 | 2.7 | 8.1% |
| | | 500 | 1,049 | 11.9 | 48.1 | 5.3 | 11.0% |
| Directional EISA 2014 Exempt, 2020 Non-Exempt | **R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)** | 420 | 472 | 6.6 | 33.4 | 3.4 | 10.0% |
| | | 473 | 524 | 7.3 | 37.7 | 3.8 | 10.0% |
| | | 525 | 714 | 9.1 | 40.9 | 4.7 | 11.4% |
| | | 715 | 937 | 12.1 | 52.9 | 6.2 | 11.8% |
| | | 938 | 1259 | 16.2 | 58.8 | 8.3 | 14.0% |
| | | 1260 | 1399 | 19.6 | 70.4 | 10.0 | 14.2% |
| | | 1400 | 1739 | 23.1 | 76.9 | 11.8 | 15.3% |
| | | 1740 | 2174 | 28.8 | 91.2 | 14.7 | 16.1% |
| | | 2175 | 2624 | 35.3 | 114.7 | 18.0 | 15.7% |
| | | 2625 | 2999 | 41.3 | 133.7 | 21.1 | 15.8% |
| | | 3000 | 4500 | 55.1 | 144.9 | 28.2 | 19.5% |
| | ***R, BR, and ER with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 499 | 7.0 | 38.0 | 3.6 | 9.4% |
| | | 500 | 649 | 8.5 | 41.5 | 4.3 | 10.4% |
| | | 650 | 1199 | 13.6 | 51.4 | 7.0 | 13.5% |
| | ***ER30, BR30, BR40, or ER40** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 499 | 7.0 | 38.0 | 3.6 | 9.4% |
| | | 500 | 649 | 8.5 | 41.5 | 4.3 | 10.4% |
| | ***BR30, BR40, or ER40** | 650 | 1419 | 15.2 | 49.8 | 7.8 | 15.6% |
| | ***R20** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 719 | 8.6 | 36.4 | 4.4 | 12.1% |
| | ***All reflector lamps below lumen ranges specified above** | 200 | 299 | 3.7 | 16.3 | 1.9 | 11.5% |
| | | 300 | 399 | 5.1 | 24.9 | 2.6 | 10.6% |
| EISA Non-Exem | **Dimmable Twist, Globe (less than 5"** | 310 | 749 | 6.7 | 22.3 | 5.0 | 22.6% |
| | | 750 | 1049 | 11.4 | 31.6 | 8.6 | 27.1% |

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage ($Watts_{EE}$) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 01/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| | **in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 1050 | 1489 | 16.1 | 36.9 | 12.1 | 32.8% |
| | | 1490 | 2600 | 26.0 | 46.0 | 19.5 | 42.3% |

**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 (Year 1) should be applied.

**HEATING PENALTY**

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

ΔkWh[898] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49%[899] for interior location

= 0% for exterior location

= 42%[900] for unknown location

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [901]:

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

[899] 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.

[900] 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.

[901] 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

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[902] | N/A | N/A | 1.28 |

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location with a 2016 heat pump:

ΔkWh = - (((45 - 13) / 1000) * 0.840 * (1 – 0.02) * 763 * 0.49) / 2.04

= - 4.83 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((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[903] |
| Multifamily in unit | 1.07[904] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.083[905] |

Use Multifamily if: Building meets utility's definition for multifamily

CF = Summer Peak Coincidence Factor for measure

= 0.109 for residential and in-unit multifamily bulbs[906], 0.273 for exterior bulbs[907] and 0.117 for

losses. Defaults provided assume 15% duct loss for heat pumps.

902 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.

903 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.

904 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

905 Unknown is weighted average of interior v exterior (assuming 15% exterior specialty 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.

906 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.

907 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 specialty LEDs in exterior applications.

unknown[908].

Use Multifamily if: Building meets utility's definition for multifamily

Other factors as defined above

> For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location:
>
> ΔkW = (((45 - 13) / 1000) * 0.840 * (1 – 0.02) * 1.11* 0.109
>
> = 0.0032 kW

**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% [909] for interior

= 0% for exterior location

= 42%[910] for unknown location

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [911]

Other factors as defined above

> For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in single family interior location with gas heating at 70% total efficiency:
>
> Δtherms = - (((45 - 13) / 1000) * 0.840 * (1 – 0.02) * 763 * 0.49* 0.03412) / 0.70
>
> = - 0.49 therms

---

[908] 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.

[909] Average result from REMRate modeling of several different configurations and IL locations of homes

[910] 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.

[911] 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

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

Bulb replacement costs assumed in the O&M calculations are provided below[912].

| Lamp Type | Installation Year | Standard Incandescent | EISA Compliant Halogen | CFL |
|---|---|---|---|---|
| Decorative | 2019 | $1.74 | N/A | N/A |
| | 2020 | $1.74 | N/A | N/A |
| | 2021 & after | $1.74 | N/A | $2.50 |
| Directional | 2019 | $3.53 | N/A | N/A |
| | 2020 | $3.53 | N/A | N/A |
| | 2021 & after | $3.53 | N/A | $4.50 |

For non-exempt EISA bulb types defined above, in order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

| Installation Location | Specialty LED Measure Hours | Hours of Use per year [913] | Measure Life in Years (capped at 10) |
|---|---|---|---|
| Interior | 15,000 | 763[914] | 10 |
| Exterior | 15,000 | 2,475[915] | 6.1 |
| Unknown | 15,000 | 1,020[916] | 10 |

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below[917].

**Decorative Lamps**

| Location | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Interior | $6.15 | $5.03 | $3.92 | $0.63 | $0.52 | $0.40 |
| Exterior | $20.17 | $16.56 | $10.39 | $3.38 | $2.78 | $1.74 |
| Unknown | $6.84 | $5.60 | $4.36 | $0.70 | $0.57 | $0.45 |

[912] Baseline costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
[913] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluations.
[914] 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.
[915] 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 specialty LEDs in exterior applications.
[916] 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 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.
[917] See "Specialty LED EISA compliant O&M Calc_2018_Adj2024.xlsx" for calculation.

**Directional Lamps**

| Location | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Interior | $12.26 | $9.96 | $7.65 | $1.26 | $1.02 | $0.78 |
| Exterior | $40.76 | $33.31 | $20.65 | $6.84 | $5.59 | $3.46 |
| Unknown | $13.64 | $11.08 | $8.52 | $1.40 | $1.14 | $0.87 |

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-LEDD-V09-190101**

**REVIEW DEADLINE: 1/1/2020**

## 5.5.7 LED Exit Signs

### Description

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a MultiFamily building within unit (use 4.5.5 Commercial Exit Signs for multifamily common area exit signs). Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is assumed to be an exit sign illuminated by LEDs.

### Definition of Baseline Equipment

The baseline equipment is assumed to be an existing fluorescent or incandescent model.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 5 years[918].

### Deemed Measure Cost

The actual material and labor costs should be used if available. If actual costs are unavailable, assume a total installed cost of at $32.50.[919]

### Loadshape

Loadshape C53 - Flat

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 100%[920].

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * WHF_e$$

Where:

WattsBase = Actual wattage if known, if unknown assume the following:

[918] Estimate of remaining life of existing unit being replaced.

[919] Price includes new exit sign/fixture and installation. LED exit cost/unit is $22.50 from the NYSERDA Deemed Savings Database and assuming I labor cost of 15 minutes @ $40/hr.

[920] Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

| Baseline Type | $Watts_{Base}$ |
|---|---|
| Incandescent | 35W[921] |
| CFL (dual sided) | 14W[922] |
| CFL (single sided) | 7W |
| Unknown | 7W |

WattsEE = Actual wattage if known, if singled sided or unknown assume 2W, if dual sided assume 4W.[923]

HOURS = Annual operating hours

= 8766

$WHF_e$ = Waste heat factor for energy; accounts for cooling savings from efficient lighting.

= 1.04[924]

Default if replacing incandescent fixture

ΔkWh = (35 – 2)/1000 * 8766 * 1.04

= 301 kWh

Default if replacing dual sided fluorescent fixture

ΔkWh = (14 – 4)/1000 * 8766 * 1.04

= 91 kWh

Default if replacing single sided fluorescent (or unknown) fixture

ΔkWh = (7 – 2)/1000 * 8766 * 1.04

= 46 kWh

**HEATING PENALTY**

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

ΔkWh[925] = - (((WattsBase - WattsEE) / 1000) * Hours * HF) / ηHeat

Where:

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

= 49%[926]

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921 Based on review of available product.

922 Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

923 Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

924 The value is estimated at 1.04 (calculated as 1 + (0.45*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 3.1 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

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

926 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.

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [927]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[928] | N/A | N/A | 1.28 |

For example, a 2.0 COP (including duct loss) Heat Pump heated building:

If incandescent fixture: ΔkWh = -((35 – 2)/1000 * 8766 * 0.49) / 2

= -71 kWh

If unknown fixture ΔkWh = -((7 – 2)/1000 * 8766 * 0.49) / 2

= -10.7 kWh

### Summer Coincident Peak Demand Savings

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

Where:

$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. The cooling savings are only added to the summer peak savings.

=1.07[929]

CF = Summer Peak Coincidence Factor for measure

= 1.0

Default if incandescent fixture

ΔkW = (35 – 2)/1000 * 1.07 * 1.0

= 0.035 kW

Default if dual sided fluorescent fixture

ΔkW = (14 – 4)/1000 * 1.07 * 1.0

= 0.0107 kW

[927] 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.

[928] 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.

[929] The value is estimated at 1.11 (calculated as 1 + (0.45 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

Default if single sided fluorescent fixture

ΔkW = (7 – 2)/1000 * 1.07 * 1.0

= 0.0054 kW

### NATURAL GAS SAVINGS

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

ΔTherms = - (((WattsBase - WattsEE) / 1000) * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49% [930]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [931]

Other factors as defined above

Default if incandescent fixture

ΔTherms = - (((35 - 2) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -6.9 therms

Default if dual sided fluorescent fixture

ΔTherms = - (((14 - 4) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -2.1 therms

Default if single sided fluorescent fixture

ΔTherms = - (((7 - 2) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -1.05 therms

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

| | Baseline Measures | |
|---|---|---|
| Component | Cost | Life (yrs) |

[930] Average result from REMRate modeling of several different configurations and IL locations of homes

[931] 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

| | Baseline Measures | |
|---|---|---|
| Lamp | $12.45[932] | 1.37 years[933] |

**MEASURE CODE: RS-LTG-LEDE-V03-190101**

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

[932] Consistent with assumption for a Standard CFL bulb ($2.45) with an estimated labor cost of $10 (assuming $40/hour and a task time of 15 minutes).
[933] Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.

## 5.5.8 LED Screw Based Omnidirectional Bulbs

### DESCRIPTION

This characterization provides savings assumptions for LED Screw Based Omnidirectional (e.g. A-Type lamps) lamps within the residential and multifamily sectors. This characterization assumes that the LED lamp 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[934].

This measure was developed to be applicable to the following program types: TOS, NC, EREP, KITS.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.1 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 requires replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen or incandescent lamp potentially spanning past 1/1/2020, this shift under the EISA backstop provision is assumed to not to occur until 1/1/2021.

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

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 6.1 years[935] for exterior application. For all other applications, lifetimes are capped at 10 years[936].

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[937].

### 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[938]:

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[934] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2018.xlsx'.

[935] ENERGY STAR v2.1 requires omnidirectional LED bulbs to be rated for at least 15,000 hours. 15000/2475 (exterior hours of use) = 6.1 years.

[936] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

[937] Representing a third of the expected lamp lifetime.

[938] 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.

| Year | EISA Compliant Halogen | LED A-Lamp | Incremental Cost |
|---|---|---|---|
| 2019 | $1.25 | $3.11 | $1.86 |
| 2020 and on | | $2.70 | $1.45 |

**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[939], 0.273 for exterior bulbs[940] and 0.135 for unknown[941].

Use Multifamily if: Building meets utility's definition for multifamily

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WH_e$$

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the "LED New and Baseline Assumptions" table for default values.

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below:[942]

**LED New and Baseline Assumptions Table**

| Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage[943] (WattsEE) | Baseline 2014-2020 (WattsBase) | Delta Watts 2014-2020 (WattsEE) | Baseline From 1/1/2021[944] (WattsBase) | Delta Watts From 1/1/2021 (WattsEE) |
|---|---|---|---|---|---|---|---|
| 5280 | 6209 | 5745 | 72.9 | 300.0 | 227.1 | 300.0 | 227.1 |
| 3301 | 5279 | 4290 | 54.5 | 200.0 | 145.5 | 200.0 | 145.5 |
| 2601 | 3300 | 2951 | 37.5 | 150.0 | 112.5 | 65.5 | 28.1 |
| 1490 | 2600 | 2045 | 26.0 | 72.0 | 46.0 | 45.4 | 19.5 |

[939] 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.

[940] 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.

[941] 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.

[942] See file "LED baseline and EE wattage table_2018.xlsx" for details on lamp wattage calculations.

[943] 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.

[944] Calculated as 45lm/W for all EISA non-exempt bulbs.

| Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage [943] (WattsEE) | Baseline 2014-2020 (WattsBase) | Delta Watts 2014-2020 (WattsEE) | Baseline From 1/1/2021[944] (WattsBase) | Delta Watts From 1/1/2021 (WattsEE) |
|---|---|---|---|---|---|---|---|
| 1050 | 1489 | 1270 | 16.1 | 53.0 | 36.9 | 28.2 | 12.1 |
| 750 | 1049 | 900 | 11.4 | 43.0 | 31.6 | 20.0 | 8.6 |
| 310 | 749 | 530 | 6.7 | 29.0 | 22.3 | 11.8 | 5.0 |
| 250 | 309 | 280 | 3.5 | 25.0 | 21.5 | 25.0 | 21.5 |

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 |
|---|---|---|---|---|---|
| Retail (Time of Sale) | | 78.4%[945] | 10.6% | 9.0% | 98.0%[946] |
| Direct Install | | 96.9%[947] | | | |
| Efficiency Kits[948] | LED Distribution[949] | 59% | 13% | 11% | 83% |
| | School Kits[950] | 60% | 13% | 11% | 84% |
| | Direct Mail Kits[951] | 66% | 14% | 12% | 93% |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[952]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below[953]:

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945 1st year in service rate is based upon analysis of ComEd PY7, PY8, and PY9 and Ameren PY8 intercept data (see 'RES Lighting ISR_2018.xlsx' for more information).

946 The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

947 Based upon Standard CFL assumption in the absence of better data, and is based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

948 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.

949 Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

950 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

951 Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

952 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.

953 Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY8 for Ameren (see for more information).

ComEd: 0.7%

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[954] |
| Exterior | 2,475[955] |
| Unknown | 1,159[956] |

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

| Bulb Location | WHFe |
|---|---|
| Interior single family | 1.06 [957] |
| Multifamily in unit | 1.04 [958] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.051[959] |

**Mid Life Baseline Adjustment**

For non-exempt lamps, an appropriate baseline adjustment should be included to account for the 2020 EISA backstop provision making replacement baseline lamps meet 45 lumens/watt. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

For example, for 60W equivalent bulbs installed in 2018, the full savings (as calculated above in the Algorithm) should be claimed for the first three years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

Note for early replacement measures an additional baseline shift accounting for the replacement of the existing unit with a new baseline lamp should be accounted for.

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954 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.

955 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.

956 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.

957 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)

958 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

959 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.

| Minimum Lumens | Maximum Lumens | LED Wattage (WattsEE) | Delta Watts 2014-2019 (WattsEE) | Delta Watts From 1/1/2021 (WattsEE) | Mid Life adjustment (made from 01/2021) to first year savings |
|---|---|---|---|---|---|
| 2601 | 3300 | 37.5 | 112.5 | 28.1 | 25.0% |
| 1490 | 2600 | 26.0 | 46.0 | 19.5 | 42.3% |
| 1050 | 1489 | 16.1 | 36.9 | 12.1 | 32.8% |
| 750 | 1049 | 11.4 | 31.6 | 8.6 | 27.1% |
| 310 | 749 | 6.7 | 22.3 | 5.0 | 22.6% |

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:

$$\Delta kWh = ((29.0 - 6.7) /1000) * 0.784 * (1 - 0.007) * 1{,}089 * 1.06$$

$$= 20.0 \text{ kWh}$$

This value should be claimed for two years, i.e. 2019-2020, but from 2021 until the end of the measure life for that same bulb, savings should be reduced to (20.0 * 0.226 =) 4.5 kWh for the remainder of the measure life. Note these adjustments should be applied to kW and fuel impacts as well.

**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.

Using the example from above, for an 8W LED, 450 Lumens purchased for the interior of a residential homes through a ComEd upstream program.

$$\Delta kWh_{2nd\ year\ installs} = ((29 - 6.7)/1000) * 0.106 * (1 – 0.007) * 1{,}089 * 1.06$$

$$= 2.7 \text{ kWh}$$

$$\Delta kWh_{3rd\ year\ installs} = ((29 - 6.7)/1000) * 0.09 * (1 – 0.007) * 1{,}089 * 1.06$$

$$= 2.3 \text{ kWh}$$

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):

$$\Delta kWh^{960} = - (((WattsBase - WattsEE) / 1000) * ISR * (1\text{-}Leakage) * Hours * HF) / \eta Heat$$

Where:

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

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

= 49%[961] for interior

= 0% for exterior or unheated location

= 42%[962] for unknown location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[963]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[964] | N/A | N/A | 1.28 |

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:

$\Delta kWh_{1st\ year}$ = - (((29 - 6.7) / 1000) * 0.784 * (1-0.007) * 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. The appropriate baseline shift adjustment should then be applied to all installs.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((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[965] |
| Multifamily in unit | 1.07[966] |

[961] 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.

[962] 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.

[963] 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.

[964] 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.

[965] 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.

[966] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table

| Bulb Location | WHFd |
|---|---|
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.093[967] |

CF = Summer Peak Coincidence Factor for measure.

| Bulb Location | CF |
|---|---|
| Interior | 0.128[968] |
| Exterior | 0.273[969] |
| Unknown | 0.135[970] |

Other factors as defined above

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 * (1-0.007) * 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. The appropriate baseline shift adjustment should then be applied to all installs.

**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% [971] for interior

= 0% for exterior location

= 42%[972] for unknown location

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)

[967] 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.

[968] 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.

[969] 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.

[970] 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.

[971] Average result from REMRate modeling of several different configurations and IL locations of homes

[972] 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.

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [973]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Bulb replacement costs assumed in the O&M calculations are provided below[974].

In order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

| Installation Location | Omnidirectional LED Measure Hours | Hours of Use per year | Measure Life in Years (capped at 10) |
|---|---|---|---|
| Residential and in-unit Multi Family | 15,000 | 1,089[975] | 10 |
| Exterior | 15,000 | 2,475[976] | 6.1 |
| Unknown | 15,000 | 1,159[977] | 10 |

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below[978]. 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:

| Location | Lumen Level | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Residential and in-unit Multi Family | Lumens <310 or >3300 (non-EISA compliant) | $4.10 | $4.10 | $4.10 | $0.42 | $0.42 | $0.42 |
| | Lumens ≥ 310 and ≤ 3300 (EISA compliant) | $3.42 | $2.34 | $2.34 | $0.35 | $0.24 | $0.24 |

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973 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

974 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.

975 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.

976 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.

977 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.

978 See “LED TRM Examples_2018.xlsx” for calculation.

| Location | Lumen Level | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Exterior | Lumens <310 or >3300 (non-EISA compliant) | $5.96 | $5.96 | $5.96 | $1.00 | $1.00 | $1.00 |
| | Lumens ≥ 310 and ≤ 3300 (EISA compliant) | $7.34 | $4.87 | $3.64 | $1.23 | $0.82 | $0.61 |
| Unknown | Lumens <310 or >3300 (non-EISA compliant) | $4.36 | $4.36 | $4.36 | $0.45 | $0.45 | $0.45 |
| | Lumens ≥ 310 and ≤ 3300 (EISA compliant) | $3.64 | $2.49 | $2.49 | $0.37 | $0.25 | $0.25 |

Note incandescent lamps in lumen range <310 and >3300 are exempt from EISA. For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[979] The replacement cycle is based on the location of the lamp and varies based on the hours of use for that location. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement.

**MEASURE CODE: RS-LTG-LEDA-V07-190101**

**REVIEW DEADLINE: 1/1/2020**

[979] The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.

## 5.5.9 LED Fixtures

### DESCRIPTION

This characterization provides savings assumptions for LED Fixtures and is broken into four ENERGY STAR fixture types: Indoor Fixtures (including track lighting, wall-wash, sconces, ceiling and fan lights), Task and Under Cabinet Fixtures, Outdoor Fixtures (including flood light, hanging lights, security/path lights, outdoor porch lights), and Downlight Fixtures.

For upstream programs, utilities should develop an assumption of the residential v commercial split and apply the relevant assumptions to each portion. A default deemed split of 97% Residential and 3% Commercial assumptions can be used based on Omnidirectional Bulbs[980].

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new fixtures must be ENERGY STAR labeled based upon the v2.1 ENERGY STAR specification for luminaires. Specifications are as follows:

| Fixture Category | Lumens/Watt |
|---|---|
| Indoor | 65 |
| Task and Under Cabinet | 50 |
| Outdoor | 60 |
| Downlight | 55 |

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an average of EISA-equivalent wattages for ENERGY STAR-qualified products. An EISA backstop provision requires replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen or incandescent lamp potentially spanning past 1/1/2020, this shift under the EISA backstop provision is assumed to not to occur until 1/1/2021.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of a fixture is a function of its rated life and average hours of use. The rated life is 47,000 hours for indoor and downlight, 45,000 for task and cabinet, and 49,000 for outdoor fixtures[981]. This would imply a lifetime of 51 years for indoor and downlight, 62 years for task and under cabinet, and 20 years for outdoor fixtures. However, all fixture lifetimes are capped at 15 years[982] so a 15 year measure life should be assumed.

### DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:

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[980] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2018.xlsx'.

[981] Average rated lives are based on the average rated lives of fixtures available on the ENERGY STAR qualifying list as of 2/26/2018.

[982] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

| Fixture Category | Incremental Cost |
|---|---|
| Indoor | $26[983] |
| Task /Under Cabinet | $18[984] |
| Outdoor | $26 |
| Downlight | $13 |

**LOADSHAPE**

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor is assumed to be 0.119 for residential and in-unit multifamily fixtures[985], 0.273 for exterior fixtures[986] and 0.127 for unknown[987].

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WHF_e$$

Where:

$Watts_{Base}$ = Baseline is an average of lumen-equivalent EISA wattages for ENERGY STAR products within the fixture category;[988] see table below

$Watts_{EE}$ = Actual wattage of LED fixture purchased / installed - If unknown, use default provided below[989]

| Fixture Category | $Watts_{Base}$ | $Watts_{EE}$ |
|---|---|---|
| Indoor | 88.5 | 22.4 |
| Task /Under Cabinet | 45.2 | 11.6 |
| Outdoor | 79.6 | 18.3 |
| Downlight | 72.8 | 20.3 |

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

983 Incremental costs for indoor and outdoor fixtures based on ENERGY STAR Light Fixtures and Ceiling Fans Calculator, which cites “EPA research on available products, 2012.” ENERGY STAR cost assumptions were reduced by 20% to account for falling LED prices.

984 Incremental costs for task/under cabinet and downlight fixtures are from the 2018 Michigan Energy Measures Database.

985 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. Average of values for standard and specialty bulbs.

986 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.

987 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.

988 See “Analysis” tab within file Residential LED Fixtures_Analysis_June 2018.xlsx for baseline calculations.

989 Average of ENERGY STAR product category watts for products at or above the version 2.1 efficacy specification

= 1.0[990]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[991]) of the Utility Jurisdiction.

Upstream (TOS) Lighting programs = Use deemed assumptions below[992]:

ComEd: 0.7%

Ameren: 6.6%

All other programs = 0

Hours = Average hours of use per year

| Fixture Category | Hours |
|---|---|
| Indoor and Downlight | 926[993] |
| Task/Under Cabinet | 730[994] |
| Outdoor | 2,475[995] |

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

| Bulb Location | WHFe |
|---|---|
| Interior single family | 1.06 [996] |
| Multifamily in unit | 1.04 [997] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.051[998] |

[990] ISR recommendation for fixtures in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-22.

[991] 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.

[992] Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY8 for Ameren (see for more information) for LED omnidirectional and specialty lamps. Leakage rates for fixtures are an average of rates for standard and specialty lamps, reduced by half according to TAC agreement.

[993] Assuming 365.25 days/year and average of recommended values for standard LED lamps (2.98) and specialty LED lamps (2.09) in interior locations 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

[994] Task/under cabinet hours of use are estimated at 2 hours per day.

[995] 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.

[996] 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)

[997] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[998] 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.

**Mid-Life Baseline Adjustment**

During the lifetime of a standard omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes over time (except for <310 and 3300+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift.

For example, for an LED fixture installed in 2019, the full savings (as calculated above in the algorithm) should be claimed for the first two years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

| Fixture Category | Lumens/Watt From 1/1/2021[999] | $Watts_{Base}$ From 1//1/2021[1000] | Mid Life adjustment (made from 01/1/2021) to first year savings |
|---|---|---|---|
| Indoor | 45 | 53.3 | 47% |
| Task /Under Cabinet | | 21.6 | 30% |
| Outdoor | | 46.2 | 46% |
| Downlight | | 42.6 | 43% |

For example, an indoor LED fixture is purchased through a ComEd retail program in 2019:

ΔkWh = ((88.5 – 22.4) /1000) * 1.0 * (1 – 0.007) * 926 * 1.06

= 64.4 kWh

This value should be claimed for two years, but from 2021 until the end of the measure life for that same fixture, savings should be reduced to (64.4 * 0.47) = 30.3 kWh for the remainder of the measure life. Note that these adjustments should be applied to kW and fuel impacts as well.

## HEATING PENALTY

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

ΔkWh[1001] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49%[1002] for interior location

= 0% for exterior or unheated location

= 42%[1003] for unknown location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[1004]:

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999 Lumens/watt as of 1/1/2021 is equal to the EISA minimum efficacy requirement for general service lamps in year 2020.

1000 Baseline post 2020 watts are calculated using the 2020 lumens/watt value.

1001 Negative value because this is an increase in heating consumption due to the efficient lighting.

1002 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.

1003 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.

1004 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

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (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[1005] | N/A | N/A | 1.28 |

Using the same indoor LED fixture that is installed in home with 2.0 COP Heat Pump (including duct loss) through a ComEd retail program in 2019:

$\Delta kWh_{1st\ year}$ = - (((88.5 – 22.4) / 1000) * 1.0 * (1 – 0.007) * 926 * 0.49) / 2.0

= - 14.9 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * 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[1006] |
| Multifamily in unit | 1.07[1007] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.093[1008] |

CF = Summer Peak Coincidence Factor for measure.

| Bulb Location | CF |
|---|---|
| Interior | 0.119[1009] |

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.

[1005] 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.

[1006] 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.

[1007] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[1008] 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.

[1009] 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. Average of values for standard and specialty bulbs.

| Bulb Location | CF |
|---|---|
| Exterior | 0.273[1010] |
| Unknown | 0.127[1011] |

Other factors as defined above

For the same indoor LED fixture that is installed in a single family interior location through a ComEd retail program in 2019, the demand savings are:

ΔkW = ((88.5 – 22.4) / 1000) * 1.0 * (1-0.007) * 1.11 * 0.119

= 0.0087 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

**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% [1012] for interior or unknown location

= 0% for exterior location

= 42%[1013] for unknown location

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1014]

[1010] 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.

[1011] 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.

[1012] Average result from REMRate modeling of several different configurations and IL locations of homes

[1013] 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.

[1014] 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

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

Bulb replacement costs assumed in the O&M calculations are provided below[1015].

| Year | Standard Incandescent | CFL |
|---|---|---|
| 2019 | $1.90 | N/A |
| 2020 | $1.90 | N/A |
| 2021 & after | $1.90 | $3.15 |

In order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

| Fixture Type | Fixture Hours | Hours of Use per year | Measure Life in Years (capped at 15) |
|---|---|---|---|
| Indoor and Downlight | 47,000 | 926[1016] | 15 |
| Task/Under Cabinet | 45,000 | 730[1017] | |
| Outdoor | 49,000 | 2,475[1018] | |

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below[1019]. 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:

| Location | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Indoor and Downlight | $5.38 | $3.93 | $3.93 | $0.37 | $0.27 | $0.27 |
| Task/Under Cabinet | $4.24 | $3.10 | $3.10 | $0.29 | $0.21 | $0.21 |
| Outdoor | $17.18 | $13.29 | $10.50 | $1.19 | $0.92 | $0.73 |

[1015] 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. Costs for standard, decorative, and directional bulbs were averaged.

[1016] Assuming 365.25 days/year and average of recommended values for standard LED lamps (2.98) and specialty LED lamps (2.09) in interior locations 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

[1017] Task/under cabinet hours of use are estimated at 2 hours per day.

[1018] 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.

[1019] See “LED TRM Examples_2018.xlsx” for calculation.

**MEASURE CODE: RS-LTG-LDFX-V01-190101**

**REVIEW DEADLINE: 1/1/2020**

## 5.5.10 Holiday String Lighting

### Description

This measure categorizes the savings from customers handing in incandescent string lighting typically used during the holidays and receiving equivalent LED string lighting. LED bulbs on string lights can consume up to 98% less power when compared to incandescent bulbs. Besides less energy to operate, LED string lighting offers many other advantages over incandescent: longer bulb life, a higher brightness, less heat buildup making them safer especially when used indoors on live trees, and better durability since they use a plastic covering over the diode instead of a glass bulb.[1020]

This measure applies to mini, C7, and C9 bulb shape types used in residential locations. Description of the bulb types of string lighting are listed below: [1021, 1022]

Mini: About 1/4" wide x 5/8" high with a shape described as a miniature candle with a pointed tip. The mini is the most common type of string light today and shares about 80% of the market. They have a female-to-male push type base.

C7: Approximately 1" wide x 1-1/2" high with a shape described as a strawberry. The C7 (and C9) are thought of as more "old fashioned" or traditional since they were the first types of string lighting used for decorative purposes. The C7 shares about 7% of the market and has a screw-in E12 candelabra base.

C9: Similar in shape to the C7, the C9 is slightly larger at 1-1/4" wide x 2-1/2" high. The C9 shares about 5% of the market and has a screw-in E17 intermediate base.

A third variant of the "C" bulb exists, which is called C6. However, due to lack of availability of the C6 incandescent from retailers, it is assumed the market has already adopted the LED as the baseline for this bulb shape type and should not be claimed for utility program savings.

The implementation strategy for this measure is only geared towards residential customers. Furthermore, the deemed hours of operation are sourced on residential only. As such, the proposed deemed split of 100% Residential and 0% Commercial assumptions should be used.

This measure was developed to be applicable to the following program types: EREP. To ensure that the baseline is appropriate, the measure is limited to an exchange event where the customer has to turn in a string of inefficient lighting.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure, new string lights must be LED and one of the eligible bulb shape categories listed in this measure (mini, C7, C9).

Some manufacturers offer integrated "smart" control of new LED strings; however, these are not included in this measure.

### Definition of Baseline Equipment

The baseline condition is the existing incandescent mini, C7, or C9 string lighting turned in during an exchange event.

### Deemed Lifetime of Efficient Equipment

The rated lifespan of LED bulbs for string lighting is in the range of 20,000 to 100,000 hours of use. However, the

[1020] See 'Christmas Lights Buying Guide – Hayneedle'.
[1021] See 'Christmas Lights Buying Guide – Hayneedle'.
[1022] See 'Christmas Lights Guide Visual'.

measure lifetime is capped at 7 years due to wear on bulbs and string from weather, sunlight, and annual installation and storage.[1023]

### Deemed Measure Cost

Where possible, the actual, full cost of new LED string lighting should be used. If unavailable, assume the following costs.

| Bulb Type | Measure Cost[1024] |
|---|---|
| Mini | $15.38 |
| C7 | $21.42 |
| C9 | $17.28 |

Loadshape

Loadshape R16; Residential Holiday String Lighting

### Coincidence Factor

Due to the seasonal nature and evening operation of holiday string lights, there is no expected reduction in a utility's peak demand.

## Algorithm

### Calculation of Energy Savings

### Electric Energy Savings

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WHF_e$$

Where:

$Watts_{base}$ = Total wattage of the existing incandescent string lights = Bulb Wattage * # Bulbs; see table below for baseline bulb wattage assumptions

$Watts_{EE}$ = Actual total wattage of the new LED string lights = Bulb Wattage * # Bulbs. If unknown, assume total wattage of new LED string lights = Bulb Wattage * # Bulbs; see table below for LED bulb wattage assumptions

Where:

Bulb Wattage = Reference the "Bulb Wattage Assumptions" table below.

**Bulb Wattage Assumptions[1025]**

| Type | Incandescent Bulb (Watts) | LED Bulb (Watts) |
|---|---|---|
| Mini | 0.49 | 0.11 |
| C7 | 5.00 | 0.31 |
| C9 | 7.00 | 0.13 |

[1023] LED string lighting lifetime from https://www.christmasdesigners.com/blog/how-long-do-led-christmas-lights-really-last/'How Long Do LED Christmas Lights Really Last Christmas Designers'

[1024] See file Holiday Lights Research and Calcs_2018.xlsx for CLEAResult research on holiday string lighting costs.

[1025] Average wattages provided from market research by CLEAResult. See file Holiday Lights Research and Calcs_2018.xlsx.

# Bulbs = Actual quantity of bulbs on the string. If baseline is unknown, assume same as the new string.

ISR = In Service Rate, or percentage of string lights that get installed. Derive from program evaluation analysis, otherwise assume 100%.

Leakage = Adjustment to account for the percentage of program string lights that move out (and in, if deemed appropriate) of the Utility Jurisdiction.

= For an exchange event, assume 0% if customer is required to be a utility customer. If not, determine leakage rate through evaluation. If customer is not required to be utility customer and if leakage is not determined through evaluation, use the deemed leakage rates LED omnidirectional bulbs sold through Upstream (TOS) programs:[1026]:

ComEd: 0.7%

Ameren: 13.1%

Hours = Average hours of use per year

= 210 hours[1027]

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting, assumed value of 1.0 since operation of string lights (if indoors) does not coincide with cooling season and there are no interactive effects for outdoor string lights.

For example, a customer replaces a 50-bulb mini incandescent string with a 50-bulb mini LED string:

ΔkWh = ((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 1.0

= 4.0 kWh

### HEATING PENALTY

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

ΔkWh[1028] = - (((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 or unknown location[1029]
= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available, use:[1030]

[1026] Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY8 for Ameren (see for more information).
[1027] Based on typical holiday lighting hours of use (6 hours per day, 7 days per week for 5 weeks) from California Municipal Utilities Association "TRM 205 LED Holiday Lights."
[1028] Negative value because this is an increase in heating consumption due to the efficient lighting.
[1029] 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.
[1030] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

| System Type | 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 |
| Unknown[1031] | N/A | N/A | 1.28 |

Using the same 50-bulb mini LED string that is installed in home with 2.0 COP Heat Pump (including duct loss):

ΔkWh = - ((((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 0.49) / 2.0

= - 1.0 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

Heating penalty if installed in a 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 or unknown location [1032]

= 0% for exterior location

0.03412 = Converts kWh to Therms

ηHeat = Actual heating system efficiency.

= 70% [1033]

---

[1031] 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.

[1032] Average result from REMRate modeling of several different configurations and IL locations of homes.

[1033] 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

Using the same 50-bulb mini LED string that is installed in a single family interior location with gas heating at 70% total efficiency:

Δtherms = - ((((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 0.49 * 0.03412) / 0.70

= - 0.10 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-LTG-LEDH-V01-190101**

**REVIEW DEADLINE: 1/1/2022**

## 5.5.11 LED Nightlights

### Description

This measure describes savings from LED nightlights. This characterization assumes that the LED nightlight is installed in a residential location.

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

For this characterization to apply, the high-efficiency equipment must be a qualified LED nightlight.

### Definition of Baseline Equipment

The baseline condition is assumed to be an incandescent/halogen nightlight.

### Deemed Lifetime of Efficient Equipment

The estimated useful life of the is estimated is 8 years[1034].

### Deemed Measure Cost

Where possible, the actual cost should be used and compared to the baseline cost. If the incremental cost is unknown, assume the following[1035]:

| Bulb Type | Year | Incandescent | LED | Incremental Cost |
|---|---|---|---|---|
| Nightlights | All | $2.84 | $6.19 | $3.35 |

### Loadshape

Loadshape R07 - Residential Outdoor Lighting

### Coincidence Factor

Demand savings is assumed to be zero for this measure.

## Algorithm

### Calculation of Savings

### Electric Energy Savings

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

Where:

$Watts_{base}$ = Actual wattage if known, if unknown, assume 7W[1036].

[1034] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2. and p.3.
[1035] Average cost data provided in Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March, 2018.
[1036] Based on Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March, 2018.

$Watts_{EE}$ = Actual wattage of LED purchased / installed.

ISR = In Service Rate or the percentage of nightlights rebated that get installed

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| Retail (Time of Sale) | 84.0%[1037] | 7.6% | 6.4% | 98.0%[1038] |
| Direct Install | 96.9%[1039] | | | |
| School Kits | 60%[1040] | 13% | 11% | 84% |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[1041]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below[1042]:

ComEd: 2.0%

Ameren: 13.1%

Hours = Average hours of use per year

= 4,380[1043]

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

| Bulb Location | WHFe |
|---|---|
| Interior single family | 1.06 [1044] |

1037 1st year in service rate is based upon analysis of ComEd PY7, PY8, and PY9 intercept data (see 'Res Lighting ISR_2018.xlsx' for more information).

1038 The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

1039 Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

1040 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

1041 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.

1042 Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY5,6 and 8 for Ameren (see for more information).

1043 Assumes nightlight is operating 12 hours per day, consistent with the 2016 Pennsylvania TRM.

1044 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

| Bulb Location | WHFe |
|---|---|
| Multifamily in unit | 1.04 [1045] |
| Unknown location | 1.054 [1046] |

For example, a 0.3W LED nightlight is direct installed in single family interior location within ComEd territory:

ΔkWh = ((7 – 0.3) / 1000) * 0.969 * (1 – 0) * 4380 * 1.06

= 30.1 kWh

**HEATING PENALTY**

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

ΔkWh[1047] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / ηHeat

Where:

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

= 49%[1048] for interior

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [1049]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.69 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[1050] | N/A | N/A | 1.28 |

Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[1045] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[1046] Unknown is 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.

[1047] Negative value because this is an increase in heating consumption due to the efficient lighting.

[1048] 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.

[1049] 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.

[1050] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

For example, a 0.3W LED nightlight is direct installed in single family interior location with a 2016 heat pump:

ΔkWh = - (((7 – 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49) / 2.04

= - 6.83 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1 000) * 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 or unknown location | 1.11[1051] |
| Multifamily in unit | 1.07[1052] |
| Unknown location | 1.098[1053] |

CF = Summer Peak Coincidence Factor for measure.

= 0

**NATURAL GAS SAVINGS**

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

Δtherms = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49% [1054] for interior

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1055]

Other factors as defined above

[1051] 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.

[1052] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[1053] Unknown is 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.

[1054] Average result from REMRate modeling of several different configurations and IL locations of homes

[1055] 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

For example, a 0.3W LED nightlight is direct installed in single family interior location with gas heating at 70% total efficiency:

$$\Delta therms = - (((7 - 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49 * 0.03412) / 0.70$$

$$= - 0.68 \text{ therms}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**MEASURE CODE: RS-LTG-NITL-V01-190101**

**REVIEW DEADLINE: 1/1/2022**

# 5.6 Shell End Use

## 5.6.1 Air Sealing

### DESCRIPTION

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. Leaks are detected and leakage rates measured with the assistance of a blower-door. The algorithm for this measure can be used when the program implementation does not allow for more detailed forecasting through the use of residential modeling software.

Prescriptive savings are provided for use only where a blower door test is not possible (for example in large multi family buildings).

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be performed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

### DEFINITION OF BASELINE EQUIPMENT

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1056]

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[1057]. 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

[1056] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[1057] 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.

Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1058]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1059]

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

= 46.6%[1060]

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Preferred methodology unless blower door testing is not possible.

ΔkWh = ΔkWh_cooling + ΔkWh_heating

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 * $ADJ_{AirSealingCool}$]

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:[1061]

| 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 |

1058 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1059 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)'.

1060 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.

1061 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".

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

CDD = Cooling Degree Days

= Dependent on location[1062]:

| 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 [1063]

0.018 = Specific Heat Capacity of Air (Btu/ft$^3$*°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[1064]:

| 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 |

LM = Latent multiplier to account for latent cooling demand[1065]

| 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 |

1062 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

1063 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.

1064 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.

1065 Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc".

$ADJ_{AirSealingCool}$ = Adjustment for cooling savings to account for innacuracies in engineering algorithms[1066]

| Measure | $ADJ_{AirSealingCool}$ |
|---|---|
| Air sealing and attic insulation | 121% |
| Air sealing without attic insulation | 100% |

ΔkWh_heating = 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)]

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone, building height and exposure level:[1067]

| 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:[1068]

| 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[1069]:

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[1066] 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.

[1067] 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".

[1068] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.

[1069] 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.

| 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 |

3412 = Converts Btu to kWh

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

For example, a 2 story 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 (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%] + [(((3,400 – 2,250) / 19.4) * 60 * 24 * 5113 * 0.018) / (1.92 * 3,412)]

= 220 + 1,199

= 1,419 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3 * $ADJ_{AirSealingHeatFan}$

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1070]

29.3 = kWh per therm

$ADJ_{AirSealingHeatFan}$ = Adjustment for fan savings during heating season to account for innacuracies in engineering algorithms[1071]

| Measure | $ADJ_{AirSealingHeatFan}$ |
|---|---|
| Air sealing and attic insulation | 107% |
| Air sealing without attic insulation | 100% |

[1070] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.

[1071] 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.

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

For example, a well shielded, 2 story 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 = 76.3 * 0.0314 * 29.3 * 107%

= 75.1 kWh

***Methodology 2: Prescriptive Infiltration Reduction Measures***[1072]

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

$\Delta kWh\_heating = (\Delta kWh_{gasket} * n_{gasket} + \Delta kWh_{sweep} * n_{sweep} + \Delta kWh_{sealing} * lf_{sealing} + \Delta kWh_{WX} * lf_{WX}) * ADJ_{RxAirsealing}$

Where:

$\Delta kWh_{gasket}$ = Annual kWh savings from installation of air sealing gasket on an electric outlet

| Climate Zone (City based upon) | $\Delta kWh_{gasket}$ / 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 |

$n_{gasket}$ = Number of gaskets installed

$\Delta kWh_{sweep}$ =Annual kWh savings from installation of door sweep

| Climate Zone (City based upon) | $\Delta kWh_{sweep}$ / 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 |

$n_{sweep}$ = Number of sweeps installed

$\Delta kWh_{sealing}$ = Annual kWh savings from foot of caulking, sealing, or polyethlylene tape

| Climate Zone (City based upon) | $\Delta kWh_{sealing}$ / ft | |
|---|---|---|
| | Electric Resistance | Heat Pump |
| 1 (Rockford) | 11.6 | 5.8 |

[1072] 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.

| Climate Zone (City based upon) | $\Delta kWh_{sealing}$ / ft | |
|---|---|---|
| | Electric Resistance | Heat Pump |
| 2 (Chicago) | 11.2 | 5.6 |
| 3 (Springfield) | 9.7 | 4.8 |
| 4 (Belleville) | 7.7 | 3.9 |
| 5 (Marion) | 7.9 | 3.9 |

$lf_{sealing}$ = linear feet of caulking, sealing, or polyethylene tape

$\Delta kWh_{WX}$ = Annual kWh savings from window weatherstripping or door weatherstripping

| Climate Zone (City based upon) | $\Delta kWh_{WX}$ / 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 |

$lf_{WX}$ = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[1073].

= 80%

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[1074]:

| 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

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

1073 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.

1074 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.

= 68%[1075]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1076]

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

= 46.6%[1077]

Other factors as defined above

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

For example, a well shielded, 2 story 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:

$\Delta kW_{SSP}$ = 220 / 570 * 0.68

= 0.26 kW

$\Delta kW_{PJM}$ = 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) * $ADJ_{AirSealingGasHeat}$

Where:

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone and building height[1078]

| 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 |

[1075] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[1076] 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)'.
[1077] 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.
[1078] 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".

HDD = Heating Degree Days

= dependent on location[1079]:

| 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[1080] (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency[1081].

$ADJ_{AirSealingGasHeat}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms[1082]

| Measure | $ADJ_{AirSealingGasHeat}$ |
|---|---|
| Air sealing and attic insulation | 72% |
| Air sealing without attic insulation | 100% |

Other factors as defined above

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

For example, a 2 story 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%

= 78.5 therms

***Methodology 2: Prescriptive Infiltration Reduction Measures[1083]***

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

1079 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..

1080 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.

1081 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

1082 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.

1083 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.

$\Delta therms$ = ($\Delta therms_{gasket}$ * $n_{gasket}$ + $\Delta therms_{sweep}$ * $n_{sweep}$ + $\Delta therms_{sealing}$ * $lf_{sealing}$ + $\Delta therms_{WX}$ * $lf_{WX}$) * $ADJ_{RxAirsealing}$

Where:

$\Delta therms_{gasket}$ = Annual therm savings from installation of air sealing gasket on an electric outlet

| Climate Zone (City based upon) | $\Delta therms_{gasket}$ / gasket Gas Heat |
|---|---|
| 1 (Rockford) | 0.49 |
| 2 (Chicago) | 0.47 |
| 3 (Springfield) | 0.41 |
| 4 (Belleville) | 0.33 |
| 5 (Marion) | 0.33 |

$n_{gasket}$ = Number of gaskets installed

$\Delta therms_{sweep}$ = Annual therm savings from installation of door sweep

| Climate Zone (City based upon) | $\Delta therms_{sweep}$ / sweep Gas Heat |
|---|---|
| 1 (Rockford) | 9.46 |
| 2 (Chicago) | 9.13 |
| 3 (Springfield) | 7.92 |
| 4 (Belleville) | 6.31 |
| 5 (Marion) | 6.45 |

$n_{sweep}$ = Number of sweeps installed

$\Delta therms_{sealing}$ = Annual therm savings from foot of caulking, sealing, or polyethlylene tape

| Climate Zone (City based upon) | $\Delta therms_{sealing}$ / ft Gas Heat |
|---|---|
| 1 (Rockford) | 0.54 |
| 2 (Chicago) | 0.52 |
| 3 (Springfield) | 0.45 |
| 4 (Belleville) | 0.36 |
| 5 (Marion) | 0.37 |

$lf_{sealing}$ = linear feet of caulking, sealing, or polyethylene tape

$\Delta therms_{WX}$ = Annual therm savings from window weatherstripping or door weatherstripping

| Climate Zone (City based upon) | $\Delta therms_{sx}$ / ft Gas Heat |
|---|---|
| 1 (Rockford) | 0.63 |
| 2 (Chicago) | 0.61 |
| 3 (Springfield) | 0.53 |
| 4 (Belleville) | 0.42 |
| 5 (Marion) | 0.43 |

$lf_{WX}$ = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[1084].

= 80%

**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 |
| | Furnace 90% 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[1085].

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**MEASURE CODE: RS-SHL-AIRS-V07-190101**

**REVIEW DEADLINE: 1/1/2022**

[1084] 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.

[1085] 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.

## 5.6.2. Basement Sidewall Insulation

### DESCRIPTION

Insulation is added to a basement or crawl space. Insulation added above ground in conditioned space is modeled the same as wall insulation. Below ground insulation is adjusted with an approximation of the thermal resistance of the ground. Insulation in unconditioned spaces is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no basement wall or ceiling insulation.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1086]

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[1087]. See section below for detail.

### DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

Loadshape R08 - Residential Cooling
Loadshape R09 - Residential Electric Space Heat
Loadshape R10 - Residential Electric Heating and Cooling

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

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[1086] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[1087] 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.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1088]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1089]

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

= 46.6%[1090]

## 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_heating)

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool))) * $ADJ_{BasementCool}$

R_added = R-value of additional spray foam, rigid foam, or cavity insulation.

R_old_AG = R-value value of foundation wall above grade.

= Actual, if unknown assume 1.0[1091]

L_basement_wall_total = Length of basement wall around the entire insulated perimeter (ft)

H_basement_wall_AG = Height of insulated basement wall above grade (ft)

Framing_factor = Adjustment to account for area of framing when cavity insulation is used

= 0% if Spray Foam or External Rigid Foam

= 25% if studs and cavity insulation[1092]

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:[1093]

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[1088] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1089] 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)'.

[1090] 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.

[1091] ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991.

[1092] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

[1093] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. There is a county

| Climate Zone (City based upon) | Conditioned CDD 65 | Unconditioned CDD 65[1094] |
|---|---|---|
| 1 (Rockford) | 820 | 263 |
| 2 (Chicago) | 842 | 281 |
| 3 (Springfield) | 1,108 | 436 |
| 4 (Belleville) | 1,570 | 538 |
| 5 (Marion) | 1,370 | 570 |
| Weighted Average[1095] | 947 | 325 |

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

= 0.75 [1096]

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:[1097]

| Age of Equipment | ηCool Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

$ADJ_{BasementCool}$ = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[1098].

= 80%

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= ([((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) + ((1/(R_old_BG - 1/(R_added+R_old_BG)) * L_basement_wall_total * (H_basement_wall_total - H_basement_wall_AG) * (1-Framing_factor))] * 24 * HDD) / (3,412 * ηHeat)) * $ADJ_{BasementHeat}$

Where

R_old_BG = R-value value of foundation wall below grade (including thermal resistance of

mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

1094 Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F.

1095 Weighted based on number of occupied residential housing units in each zone.

1096 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.

1097 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.

1098 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.

the earth) [1099]

= dependent on depth of foundation (H_basement_wall_total – H_basement_wall_AG):

= Actual R-value of wall plus average earth R-value by depth in table below

| Below Grade R-value | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Depth below grade (ft) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Earth R-value (°F-ft$^2$-h/Btu) | 2.44 | 4.50 | 6.30 | 8.40 | 10.44 | 12.66 | 14.49 | 17.00 | 20.00 |
| Average Earth R-value (°F-ft2-h/Btu) | 2.44 | 3.47 | 4.41 | 5.41 | 6.42 | 7.46 | 8.46 | 9.53 | 10.69 |
| Total BG R-value (earth + R-1.0 foundation) default | 3.44 | 4.47 | 5.41 | 6.41 | 7.42 | 8.46 | 9.46 | 10.53 | 11.69 |

H_basement_wall_total = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:[1100]

| Climate Zone (City based upon) | Conditioned HDD 60 | Unconditioned HDD 50 |
|---|---|---|
| 1 (Rockford) | 5,352 | 3,322 |
| 2 (Chicago) | 5,113 | 3,079 |
| 3 (Springfield) | 4,379 | 2,550 |
| 4 (Belleville) | 3,378 | 1,789 |
| 5 (Marion) | 3,438 | 1,796 |
| Weighted Average[1101] | 4,860 | 2,895 |

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:[1102]

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective 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 |

1099 Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

1100 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F for a conditioned basement and 50°F for an unconditioned basement), consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

1101 Weighted based on number of occupied residential housing units in each zone.

1102 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.

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85 |
|---|---|---|---|
| Resistance | N/A | N/A | 1 |

$ADJ_{BasementHeat}$ = Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[1103].

= 60%

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= [((((1/2.25 - 1/(13 + 2.25))*(20+25+20+25) * 3 * (1 - 0)) * 24 * 281 * 0.75)/(1000 * 10.5)) * 0.8] + [(((((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0)) + ((1 / (2.25 + 6.42) – 1 / (13 + 2.25 + 6.42)) * (20+25+20+25) * 4 * (1-0))) * 24 * 3079) / (3412 * 1.92)) * 0.6]

= (39.4 + 860.9)

= 900.3 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1104]

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section :

= 78.3 * 0.0314 * 29.3

= 72.0 kWh

**SUMMER COINCIDENT PEAK DEMAND**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= dependent on location[1105]:

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1103 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

1104 $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

1105 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

| 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[1106] | 629 | 564 |

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

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1107]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1108]

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

= 46.6%[1109]

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

$\Delta kW_{SSP}$ = 39.4 / 570 * 0.68

= 0.047 kW

$\Delta kW_{PJM}$ = 39.4 / 570 * 0.466

= 0.032 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

ΔTherms = [(([((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor) + (1/(R_old_BG - 1/(R_added+R_old_BG)) * L_basement_wall_total * (H_basement_wall_total - H_basement_wall_AG) * (1-Framing_factor)] * 24 * HDD) / (ηHeat * 100,000)] * $ADJ_{BasementHeat}$

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume 72% for existing system efficiency[1110]

Other factors as defined above

table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

1106 Weighted based on number of occupied residential housing units in each zone.

1107 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1108 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)'.

1109 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.

1110 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 72% efficient furnace:

= (((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0) + (1/8.67 - 1/(13 + 8.67)) * (20+25+20+25) * 4 * (1 - 0)) * 24 * 3079) / (0.72 * 100,000) * 0.60

= 78.3 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<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% 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 [1111].

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-SHL-BINS-V09-190101**

**REVIEW DEADLINE: 1/1/2020**

[1111] 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.

## 5.6.3. Floor Insulation Above Crawlspace

### DESCRIPTION

Insulation is added to the floor above a vented crawl space that does not contain pipes or HVAC equipment. If there are pipes, HVAC, or a basement, it is desirable to keep them within the conditioned space by insulating the crawl space walls and ground. Insulating the floor separates the conditioned space above from the space below the floor, and is only acceptable when there is nothing underneath that could freeze or would operate less efficiently in an environment resembling the outdoors. Even in the case of an empty, unvented crawl space, it is still considered best practice to seal and insulate the crawl space perimeter rather than the floor. Not only is there generally less area to insulate this way, but there are also moisture control benefits. There is a "Basement Insulation" measure for perimeter sealing and insulation. This measure assumes the insulation is installed above an unvented crawl space and should not be used in other situations.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no insulation on any surface surrounding a crawl space.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1112]

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[1113]. See section below for detail.

### DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate

[1112] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1113] 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.

peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1114]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1115]

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

= 46.6%[1116]

**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_heating)

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old - 1/(R_added+R_old)) * Area * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool))) * $ADJ_{FloorCool}$

R_old = R-value value of floor before insulation, assuming 3/4" plywood subfloor and carpet with pad

= Actual. If unknown assume 3.96 [1117]

R_added = R-value of additional spray foam, rigid foam, or cavity insulation.

Area = Total floor area to be insulated

Framing_factor = Adjustment to account for area of framing

= 12% [1118]

24 = Converts hours to days

CDD = Cooling Degree Days

[1114] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[1115] 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)'.
[1116] 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.
[1117] Based on 2005 ASHRAE Handbook – Fundamentals: assuming 2x8 joists, 16" OC, ¾" subfloor, ½" carpet with rubber pad, and accounting for a still air film above and below: 1/ [(0.85 cavity share of area / (0.68 + 0.94 + 1.23 + 0.68)) + (0.15 framing share / (0.68 + 7.5" * 1.25 R/in + 0.94 + 1.23 + 0.68))] = 3.96
[1118] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

| Climate Zone (City based upon) | Unconditioned CDD[1119] |
|---|---|
| 1 (Rockford) | 263 |
| 2 (Chicago) | 281 |
| 3 (Springfield) | 436 |
| 4 (Belleville) | 538 |
| 5 (Marion) | 570 |
| Weighted Average[1120] | 325 |

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

= 0.75 [1121]

1000 = Converts Btu to kBtu

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

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following:[1122]

| Age of Equipment | ηCool Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

$ADJ_{FloorCool}$ = Adjustment for cooling savings from floor to account for prescriptive engineering algorithms overclaiming savings[1123].

= 80%

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= ((((1/R_old - 1/(R_added + R_old)) * Area * (1-Framing_factor) * 24 * HDD)/ (3,412 * ηHeat)) * $ADJ_{FloorHeat}$

HDD = Heating Degree Days:[1124]

1119 Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F.
1120 Weighted based on number of occupied residential housing units in each zone.
1121 Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.
1122 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.
1123 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.
1124 National Climatic Data Center, Heating Degree Days with a base temp of 50°F to account for lower impact of unconditioned space on heating system. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | Unconditioned HDD |
|---|---|
| 1 (Rockford) | 3,322 |
| 2 (Chicago) | 3,079 |
| 3 (Springfield) | 2,550 |
| 4 (Belleville) | 1,789 |
| 5 (Marion) | 1,796 |
| Weighted Average[1125] | 2,895 |

ηHeat = Efficiency of heating system

= Actual.If not available refer to default table below:[1126]

| 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 |

$ADJ_{FloorHeat}$ = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings[1127].

= 60%

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= ((((1/3.96 -1/(30+3.96))*(20*25)*(1-0.12)* 24 * 281*0.75)/(1000*10.5)) * 0.8 + (((1/3.96 - 1/(30+3.96))*(20*25)*(1-0.15) * 24 * 3079)/(3412*1.92)) * 0.6)

= (37.8 + 641.7)

= 679.5 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1128]

[1125] Weighted based on number of occupied residential housing units in each zone.

[1126] 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.

[1127] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

[1128] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section):

ΔkWh = 60.4 * 0.0314 * 29.3

= 55.6 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location:[1129]

| 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[1130] | 629 | 564 |

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

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1131]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1132]

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

= 46.6%[1133]

(non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

1129 Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

1130 Weighted based on number of occupied residential housing units in each zone.

1131 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1132 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)'.

1133 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

$\Delta kW_{SSP}$ = 37.8 / 570 * 0.68

= 0.045 kW

$\Delta kW_{SSP}$ = 37.8 / 570 * 0.466

= 0.031 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

ΔTherms = (1/R_old - 1/(R_added+R_old)) * Area * (1-Framing_factor)) * 24 * HDD) / (100,000 * ηHeat) * $ADJ_{FloorHeat}$

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume 72% for existing system efficiency[1134]

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 72% efficient furnace:

ΔTherms = ((1 / 3.96 – 1 /(30 + 3.96))*(20 * 25) * (1 - 0.12) * 24 * 3079) / (100,000 * 0.72) * 0.60

= 60.4 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<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% 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 [1135].

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[1134] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

[1135] 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.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-SHL-FINS-V09-190101**

**REVIEW DEADLINE: 1/1/2020**

## 5.6.4. Wall Insulation

### DESCRIPTION

Insulation is added to wall cavities. This measure requires a member of the implementation staff evaluating the pre and post R-values and measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1136]

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[1137]. 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 Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1138]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

1136 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

1137 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.

1138 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 72%%[1139]

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

= 46.6%[1140]

**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_heating)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to wall insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * CDD * DUA) / (1000 * ηCool)) * $ADJ_{WallCool}$

R_wall = R-value of new wall 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-5 for uninsulated assemblies[1141])

A_wall = Net area of insulated wall ($ft^2$)

Framing_factor_wall = Adjustment to account for area of framing

= 25%[1142]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1143]

| 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 |

1139 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)'.
1140 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.
1141 An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).
1142 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1
1143 National Climatic Data Center, Cooling Degree Days are based on a base temp of 65°F. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | CDD 65 |
|---|---|
| Weighted Average[1144] | 947 |

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

= 0.75 [1145]

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:[1146]

| Age of Equipment | ηCool Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

$ADJ_{WallCool}$ = Adjustment for cooling savings from wall insulation to account for inaccuracies in prescriptive engineering algorithms[1147]

= 80%

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to wall insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * HDD) / (ηHeat * 3412)) * $ADJ_{WallHeat}$

HDD = Heating Degree Days

= Dependent on location:[1148]

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

1144 Weighted based on number of occupied residential housing units in each zone.

1145 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.

1146 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.

1147 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.

1148 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.

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |
| Weighted Average[1149] | 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:[1150]

| 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 |

3412 = Converts Btu to kWh

$ADJ_{WallHeat}$ = Adjustment for heating savings to account for inaccuracies in prescriptive engineering algorithms.[1151]

= 60%

For example, a single family home in Chicago with 990 ft$^2$ of R-5 walls insulated to R-11, 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((((1/5 - 1/11) * 990 * (1-0.25)) * 842 * 0.75 * 24)/ (1000 * 10.5)) * 80%) + (((((1/5 - 1/11) * 990 * (1-0.25)) * 5113 * 24) / (1.92 * 3412)) * 60%)

= 93.5 + 910

= 1,004 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

[1149] Weighted based on number of occupied residential housing units in each zone.

[1150] 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.

[1151] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.[1152] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

= 3.14%[1152]

29.3 = kWh per therm

For example, a single family home in Chicago with 990 $ft^2$ of R-5 walls insulated to R-11 with a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section):

ΔkWh = 90.3 * 0.0314 * 29.3

= 83.1 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:[1153]

| 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[1154] | 629 | 564 |

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

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1155]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%%[1156]

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

= 46.6%[1157]

---

[1152] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[1153] 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.

[1154] Weighted based on number of occupied residential housing units in each zone.

[1155] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1156] 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)'.

[1157] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

For example, a single family home in Chicago with 990 $ft^2$ of R-5 walls insulated to R-11, 10.5 SEER Central AC, and 2.26 COP Heat Pump:

$\Delta kW_{SSP}$ = 93.5 / 570 * 0.68

= 0.11 kW

$\Delta kW_{PJM}$ = 93.5 / 570 * 0.466

= 0.08 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

ΔTherms = ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * HDD) / (ηHeat * 100,000 Btu/therm) * $ADJ_{WallHeat}$

Where:

HDD = Heating Degree Days

= Dependent on location:[1158]

| 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[1159] | 4,860 |

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate).[1160] If unknown assume 72% for existing system efficiency.[1161]

Other factors as defined above

For example, a single family home in Chicago with 990 $ft^2$ of R-5 walls insulated to R-11, with a gas furnace with system efficiency of 66%:

ΔTherms = ((((1/5 - 1/11) * 990 * (1-0.25)) * 24 * 5113) / (0.66 * 100,000)) * 60%

= 90.4 therms

[1158] 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.

[1159] Weighted based on number of occupied residential housing units in each zone.

[1160] 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.

[1161] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

**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<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% 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 [1162].

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: RS-SHL-WINS-V08-190101

## REVIEW DEADLINE: 1/1/2022

[1162] 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.

## 5.6.5. 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.[1163]

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[1164]. 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 Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1165]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

[1163] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1164] 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.

[1165] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 72%%[1166]

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

= 46.6%[1167]

**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_heating)

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)) * $ADJ_{AtticCool}$

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-5 for uninsulated assemblies[1168])

A_attic = Total area of insulated ceiling/attic ($ft^2$)

Framing_factor_attic = Adjustment to account for area of framing

= 7%[1169]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1170]

| 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 |

[1166] 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)'.
[1167] 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.
[1168] An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).
[1169] Ibid.
[1170] National Climatic Data Center, Cooling Degree Days are based on a base temp of 65°F. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | CDD 65 |
|---|---|
| Weighted Average[1171] | 947 |

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

= 0.75 [1172]

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[1173]:

| 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 |

$ADJ_{AtticCool}$ = Adjustment for cooling savings to account for inaccuracies in engineering algorithms[1174]

= 121%

kWh_heating = 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)) * $ADJ_{AtticElectricHeat}$

HDD = Heating Degree Days

= Dependent on location:[1175]

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

1171 Weighted based on number of occupied residential housing units in each zone.

1172 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.

1173 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.

1174 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.

1175 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.

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |
| Weighted Average[1176] | 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[1177]:

| 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 |

3412 = Converts Btu to kWh

$ADJ_{AtticElectricHeat}$ = Adjustment for electric heating savings to account for inaccuracies in engineering algorithms[1178]

= 60%

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

For example, a single family home in Chicago installs 700 $ft^2$ 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%) + (((((1/5 - 1/38) * 700 * (1-0.07)) * 5113 * 24) / (1.92 * 3412)) * 60%)

= 197 + 1,271

= 1,468 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3 * $ADJ_{AtticHeatFan}$

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1179]

[1176] Weighted based on number of occupied residential housing units in each zone.

[1177] 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.

[1178] 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.

[1179] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a

29.3 = kWh per therm

$ADJ_{AtticHeatFan}$ = Adjustment for fan savings to account for innacuracies in engineering algorithms[1180]

= 107%

> The following example captures energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.
>
> For example, a single family home in Chicago installs 700 $ft^2$ 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:[1181]

| 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[1182] | 629 | 564 |

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

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1183]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%%[1184]

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

calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[1180] 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.

[1181] 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.

[1182] Weighted based on number of occupied residential housing units in each zone.

[1183] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1184] 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)'.

= 46.6%[1185]

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

For example, a single family home in Chicago installs 700 $ft^2$ 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:

$\Delta kW_{SSP}$ = 197 / 570 * 0.68

= 0.24 kW

$\Delta kW_{PJM}$ = 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) * $ADJ_{AtticGasHeat}$

Where:

HDD = Heating Degree Days

= Dependent on location:[1186]

| 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[1187] | 4,860 |

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[1188] (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency[1189].

$ADJ_{AtticGasHeat}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms[1190]

---

[1185] 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.

[1186] 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.

[1187] Weighted based on number of occupied residential housing units in each zone.

[1188] 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.

[1189] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

[1190] As demonstrated in air sealing and insulation research by Navigant, Navigant (2018). C*omEd and Nicor Gas Air Sealing and*

= 72%

Other factors as defined above

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

For example, a single family home in Chicago installs 700 $ft^2$ 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%

= 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<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% 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 [1191].

## Water Impact Descriptions and Calculation

N/A

## Deemed O&M Cost Adjustment Calculation

N/A

## Measure Code: RS-SHL-AINS-V01-190101

## Review Deadline: 1/1/2022

*Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

[1191] 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.

## 5.6.6. Rim/Band Joist Insulation

### DESCRIPTION

This measure describes savings from adding insulation (either rigid or spray foam) to rim/band joist cavities. This measure requires a member of the implementation staff evaluating the pre- and post-project R-values and to measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities and little or no attic insulation.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1192]

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[1193]. 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 Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1194]

1192 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

1193 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.

1194 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1195]

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

= 46.6%[1196]

**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_heating)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * CDD * 24 * DUA * ADJ_{BasementCool}}{(1000 * \eta Cool)}$$

$R_{Rim}$ = R-value of new rim/band joist 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-5 for uninsulated assemblies[1197])

$A_{Rim}$ = Net area of insulated rim/band joist ($ft^2$)

$FramingFactor_{Rim}$ = Adjustment to account for area of framing

= 5%[1198]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1199]

| Climate Zone (City based upon) | Conditioned CDD 65 | Unconditioned CDD 75[1200] |
|---|---|---|
| 1 (Rockford) | 820 | 263 |

[1195] 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)'.

[1196] 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.

[1197] An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).

[1198] Assumes the average framing factor for joists running from front-to-back (0.094) and from side-to-side (0). The front-to-back FF was calculated based on 1.5" joists for every 16" (1.5"/16" = 0.094). The side-to-side FF is 0 since joists are continuous and uninterrupted.

[1199] 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.

[1200] Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year

| Climate Zone (City based upon) | Conditioned CDD 65 | Unconditioned CDD 75[1200] |
|---|---|---|
| 2 (Chicago) | 842 | 281 |
| 3 (Springfield) | 1,108 | 436 |
| 4 (Belleville) | 1,570 | 538 |
| 5 (Marion) | 1,370 | 570 |
| Weighted Average[1201] | 947 | 325 |

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

= 0.75 [1202]

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[1203]:

| 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 |

$ADJ_{BasementCool}$ = Adjustment for cooling savings from basement wall and rim/band joist insulation to account for prescriptive engineering algorithms overclaiming savings[1204].

= 80%

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJ_{BasementHeat}}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:[1205]

climate normals from NCDC used elsewhere are not available at base temps above 72F.

1201 Weighted based on number of occupied residential housing units in each zone.

1202 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.

1203 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.

1204 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.

1205 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F for a conditioned basement and 50°F for an unconditioned basement, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | Conditioned HDD 60 | Unconditioned HDD 50 |
|---|---|---|
| 1 (Rockford) | 5,352 | 3,322 |
| 2 (Chicago) | 5,113 | 3,079 |
| 3 (Springfield) | 4,379 | 2,550 |
| 4 (Belleville) | 3,378 | 1,789 |
| 5 (Marion) | 3,438 | 1,796 |
| Weighted Average[1206] | 4,860 | 2,895 |

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[1207]:

| 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 |

3412 = Converts Btu to kWh

$ADJ_{BasementHeat}$ = Adjustment for basement wall and rim/band joist insulation to account for prescriptive engineering algorithms overclaiming savings[1208].

= 60%

For example, a single family home in Chicago with 100 ft$^2$ of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((1/5 - 1/13) * 100 * (1-0.05) * 281 * 24 * 0.75) / (1000 * 10.5)) + (((1/5 - 1/13) * 100 * (1-0.05) * 3079 * 24 * 0.60) / (1.92 * 3412))

= 5.6 + 79.1

= 84.7 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

[1206] Weighted based on number of occupied residential housing units in each zone.

[1207] 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.

[1208] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

= ΔTherms * $F_e$ * 29.3

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1209]

29.3 = kWh per therm

> For example, a single family home in Chicago with 100 ft² of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section):
>
> ΔkWh = 7.85 * 0.0314 * 29.3
>
> = 7.2 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:[1210]

| 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[1211] | 629 | 564 |

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

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1212]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%%[1213]

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

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[1209] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[1210] 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.

[1211] Weighted based on number of occupied residential housing units in each zone.

[1212] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1213] 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)'.

= 46.6%[1214]

For example, a single family home in Chicago with 100 ft$^2$ of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

$\Delta kW_{SSP}$ = 5.6 / 570 * 0.68

= 0.0067 kW

$\Delta kW_{PJM}$ = 5.6 / 570 * 0.466

= 0.0046 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJ_{BasementHeat}}{(\eta Heat * 100{,}000)}$$

Where:

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[1215] (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency[1216].

Other factors as defined above

For example, a single family home in Chicago with 100 ft$^2$ of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 66%:

ΔTherms = ((1/5 - 1/13) * 100 * (1-0.05) * 3079 * 24 * 0.60) / (0.66 * 100,000)

= 7.85 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 |
| | Furnace | 76.5% AFUE |

1214 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.

1215 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.

1216 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| | 90% AFUE * 0.85 | |
| | 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 [1217].

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-SHL-RINS-V01-190101**

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

[1217] 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.

# 5.7 Miscellaneous

## 5.7.1 High Efficiency Pool Pumps

### DESCRIPTION

Conventional residential outdoor pool pumps are single speed, often oversized, and run frequently at constant flow regardless of load. Single speed pool pumps require that the motor be sized for the task that requires the highest speed. As such, energy is wasted performing low speed tasks at high speed. Two speed and variable speed pool pumps reduce speed when less flow is required, such as when filtering is needed but not cleaning, and have timers that encourage programming for fewer on-hours. Variable speed pool pumps use advanced motor technologies to achieve efficiency ratings of 90% while the average single speed pump will have efficiency ratings between 30% and 70%[1218]. This measure is the characterization of the purchasing and installing of an efficient two speed or variable speed residential pool pump motor in place of a standard single speed motor of equivalent horsepower.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is a two speed or variable speed residential pool pump meeting the ENERGY STAR minimum qualifications for either in-ground or above ground pools. ENERGY STAR version 2.0 specification takes effect on January 1, 2019 and version 3.0 has an effective date of July 19, 2021.

| Pump Sub-Type | Size Class | ENERGY STAR Version 2.0 Energy Efficiency Level (Effective 1/1/2019) | ENERGY STAR Version 3.0 Energy Efficiency Level (Effective 7/19/2021) |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Extra Small (hhp ≤ 0.13) | WEF ≥ 7.60 | WEF ≥ 13.40 |
| | Small (hhp > 0.13 and < 0.711) | WEF ≥ -1.30 x ln (hhp) + 4.95 | WEF ≥ -2.45 x ln (hhp) + 8.40 |
| | Standard Size (hhp ≥ 0.711) | WEF ≥ -2.30 x ln (hhp) + 6.59 | WEF ≥ -2.45 x ln (hhp) + 8.40 |
| Non-Self Priming (Aboveground) Pool Pumps | Extra Small (hhp ≤ 0.13) | WEF ≥ 4.92 | WEF ≥ 4.92 |
| | Standard Size (hhp > 0.13) | WEF ≥ -1.00 x ln (hhp) + 3.85 | WEF ≥ -1.00 x ln (hhp) + 3.85 |

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a single speed residential pool pump.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for a two speed or variable speed pool pump is 7 years[1219].

### DEEMED MEASURE COST

The incremental costs for in-ground pool pumps are estimated as $235 for a two speed motor and $549 for a variable speed motor[1220].

The incremental costs for above ground pool pumps are estimated as $200 for a two speed motor and $1,130 for a

1218 U.S. DOE, 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. Report No. DOE/GO-102012-3534.

1219 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

1220 ENERGY STAR Pool Pump Calculator.

variable speed motor.[1221]

**LOADSHAPE**

Loadshape R15 – Residential Pool Pumps

**COINCIDENCE FACTOR**

The coincidence factor for this measure is assumed to be 0.831[1222].

## Algorithm

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**[1223]

ΔkWh two speed = $(((Hrs/Day_{base} * GPM_{base} * 60)/EF_{base}) - (((Hrs/Day_{2spH} * GPM_{2spH} * 60) + (Hrs/Day_{2spL} * GPM_{2spL} * 60))/WEF_{2sp}))/1000 * Days$

ΔkWh variable speed = $(((Hrs/Day_{base} * GPM_{base} * 60)/EF_{base}) - (((Hrs/Day_{vsH} * GPM_{vsH} * 60)/ + (Hrs/Day_{vsL} * GPM_{vsL} * 60)/)/WEF_{vs}))/1000 * Days$

Where:

$Hrs/Day_{base}$ = run hours of single speed pump

= 11.4 hours for in-ground pools

= 7.0 hours for above ground pools

$GPM_{base}$ = flow of single speed pump (gal/min)

= 64.4 gal/min for in-ground pools

= 36 gal/min for above ground pools

60 = minutes per hour

$EF_{base}$ = Energy Factor of baseline single speed pump (gal/Wh)

= 2.1

$Hrs/Day_{2spH}$ = run hours of two speed pump at high speed

= 2 hours for in-ground pools

= 1.2 hours for above ground pools

$GPM_{2spH}$ = flow of two speed pump at high speed (gal/min)

= 56 gal/min for in-ground pools

= 31 gal/min for above ground pools

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[1221] CEE Efficient Residential Swimming Pool Initiative, December 2012, page 18.

[1222] Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.

[1223] The methodology and all assumptions are sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.6 turnovers per day in the efficient case. For above ground pools, the turnover ratios were kept the same with the pool size being 7,540 gallons. The volume of the above ground pool is sourced from the California Urban Water Council Evaluation of Potential Best Management Practices for Pools, Spas, and Fountains for the average above ground residential pool.

$Hrs/Day_{2spL}$ = run hours of two speed pump at low speed

= 15.7 hours for in-ground pools

= 9.6 hours for above ground pools

$GPM_{2spL}$ = flow of two speed pump at low speed (gal/min)

= 31 gal/min for in-ground pools

= 17 gal/min for above ground pools

WEF = Weighted Energy Factor of the efficient pump (gal/Wh), dependent on the pool application and motor designation, as detailed in the table below[1224]:

| Pump Sub-Type | Motor Design | ENERGY STAR Version 2.0 WEF (gal/Wh) | ENERGY STAR Version 3.0 WEF (gal/Wh) |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed ($WEF_{2sp}$) | 5.31 | 8.44 |
| | Variable-speed ($WEF_{vs}$) | 6.6 | 11.05 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed ($WEF_{2sp}$) | 3.55 | 3.55 |
| | Variable-speed ($WEF_{vs}$) | 4.21 | 4.21 |

$Hrs/Day_{vsH}$ = run hours of variable speed pump at high speed

= 2 hours for in-ground pools

= 1.2 hours for above ground pools

$GPM_{vsH}$ = flow of variable speed pump at high speed (gal/min)

= 50 gal/min for in-ground pools

= 28 gal/min for above ground pools

$Hrs/Day_{vsL}$ = run hours of variable speed pump at low speed

= 16 hours for in-ground pools

= 9.8 hours for above ground pools

$GPM_{vsL}$ = flow of variable speed pump at low speed (gal/min)

= 30.6 gal/min for in-ground pools

= 17 gal/min for above ground pools

Days = Number of days per year that the swimming pool is operational

= 125[1225]

Based on the pool/pump application and the motor designation, the annual energy savings (ΔkWh) are detailed in the table below:

[1224] The efficient Weighted Energy Factor is sourced from a weighted average of products meeting the ENERGY STAR minimum qualifications and listed on their Qualified Products List (QPL), as accessed on 04/26/2018. As pump applications were not designated in the ENERGY STAR QPL, equipment sizes and horsepower were assumed similar between aboveground and inground pools.

[1225] Assumes 50% of pools operated from Memorial Day through Labor Day (100 days) and 50% of pools operate for a longer span, typically the 5 month period between May and September (150 days), due to their ability to heat the pool.

| Pump Sub-Type | Motor Design | Annual Energy Savings (ΔkWh) ENERGY STAR Version 2.0 | Annual Energy Savings (ΔkWh) ENERGY STAR Version 3.0 |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed | 1,776 | 2,090 |
| | Variable-speed | 1,952 | 2,222 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed | 465 | 465 |
| | Variable-speed | 539 | 539 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS** [1226]

ΔkW two speed = $((kWh/day_{base})/(Hrs/day_{base}) – (kWh/day_{2sp})/(Hr/day_{2sp}))$ * CF

ΔkW variable speed = $((kWh/day_{base})/(Hrs/day_{base}) – (kWh/day_{vr})/(Hr/day_{vr}))$ * CF

Where:

$kWh/day_{base}$ = daily energy consumption of baseline pump, as defined above

= 20.98 kWh/day for in-ground pools

= 7.19 kWh/day for above ground pools

$Hrs/day_{base}$ = daily run hours of single speed pump

= 11.4 hours for in-ground pools

= 7.0 hours for above ground pools

| kWh/day = daily energy consumption of the efficient pump, dependent on the pool application and motor designation, as detailed in the table below: **Pump Sub-Type** | Motor Design | Daily Energy Consumption (kWh/day) ENERGY STAR Version 2.0 | Daily Energy Consumption (kWh/day) ENERGY STAR Version 3.0 |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed ($kWh/day_{2sp}$) | 6.76 | 4.26 |
| | Variable-speed ($kWh/day_{vs}$) | 5.36 | 3.20 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed ($kWh/day_{2sp}$) | 3.47 | 3.47 |
| | Variable-speed ($kWh/day_{vs}$) | 2.88 | 2.88 |

$Hr/day_{2sp}$ = run hours of two speed pump

= 17.7 hours for in-ground pools

= 10.9 hours for above ground pools

$Hr/day_{var}$ = run hours of variable speed pump

= 18 hours for in-ground pools

= 11 hours for above ground pools

CF = Summer Peak Coincidence Factor for measure

[1226] The methodology and all assumptions are sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.5 turnovers per day in the efficient case.

= 0.831[1227]

Based on the pool/pump application and the motor designation, the summer coincident peak demand savings (ΔkW) are detailed in the table below:

| Pump Sub-Type | Motor Design | Summer Peak Coincident Demand Savings (ΔkW) ENERGY STAR Version 2.0 | Summer Peak Coincident Demand Savings (ΔkW) ENERGY STAR Version 3.0 |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed | 1.211 | 1.329 |
| | Variable-speed | 1.282 | 1.381 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed | 0.589 | 0.589 |
| | Variable-speed | 0.638 | 0.638 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-MSC-RPLP-V02-190101**

**REVIEW DEADLINE: 1/1/2021**

[1227] Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.