

2019 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0

Volume 3: Residential Measures

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VOLUME 4: CROSS-CUTTING MEASURES AND ATTACHMENTS

Volume 3: Residential Measures

5.1 Appliances End Use

5.1.1 ENERGY STAR Air Purifier/Cleaner

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust¹ 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 unit².

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 9 years³.

DEEMED MEASURE COST

The incremental cost for this measure is \$70.⁴

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

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

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

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

³ ENERGY STAR Qualified Room Air Cleaner Calculator.

⁴ Ibid

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta \text{kWh} = \text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}$$

Where:

 kWh_{BASE} = Baseline kWh consumption per year⁵

= see table below

 $\text{kWh}_{\text{ESTAR}}$ = ENERGY STAR kWh consumption per year⁶

= 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

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} * \text{CF}$$

Where:

 ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5844 hours⁷

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

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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 2018¹⁰.

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 years¹¹.

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 \$141¹².

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.

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).

$$\text{IMEFsavings}^{15} = \text{Capacity} * (1/\text{IMEFbase} - 1/\text{IMEFeff}) * \text{Ncycles}$$

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

$$\Delta kWh = [Capacity * 1/IMEF_{base} * N_{cycles} * (\%CW_{base} + (\%DHW_{base} * \%Electric_DHW) + (\%Dryer_{base} * \%Electric_Dryer))] - [Capacity * 1/IMEF_{eff} * N_{cycles} * (\%CW_{eff} + (\%DHW_{eff} * \%Electric_DHW) + (\%Dryer_{eff} * \%Electric_Dryer))]$$

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.

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

Where

$$E_{\text{water total}} = \text{IL Total Water Energy Factor (kWh/Million Gallons)} \\ = 5,010^{23}$$

Using defaults provided:

$$\text{ENERGY STAR} \quad \Delta kWh_{\text{water}} = 1159 / 1,000,000 * 5,010 \\ = 5.8 \text{ kWh}$$

$$\text{ENERGY STAR Most Efficient} \quad \Delta kWh_{\text{water}} = 1931 / 1,000,000 * 5,010 \\ = 9.7 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

$$\Delta kWh = \text{Energy Savings as calculated above Note do not include the secondary savings in this calculation.}$$

$$\text{Hours} = \text{Assumed Run hours of Clothes Washer} \\ = 264 \text{ hours}^{24}$$

$$CF = \text{Summer Peak Coincidence Factor for measure.} \\ = 0.038^{25}$$

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:

$$\Delta \text{Therm} = [(\text{Capacity} * 1 / \text{IMEF}_{\text{base}} * \text{Ncycles} * ((\% \text{DHW}_{\text{base}} * \% \text{Natural Gas}_{\text{DHW}} * R_{\text{eff}}) + (\% \text{Dryer}_{\text{base}} * \% \text{Gas}_{\text{Dryer}}))) - (\text{Capacity} * 1 / \text{IMEF}_{\text{eff}} * \text{Ncycles} * ((\% \text{DHW}_{\text{eff}} * \% \text{Natural Gas}_{\text{DHW}} * R_{\text{eff}}) + (\% \text{Dryer}_{\text{eff}} * \% \text{Gas}_{\text{Dryer}})))] * \text{Therm}_{\text{convert}}$$

Where:

$\text{Therm}_{\text{convert}}$ = Conversion factor from kWh to Therm
= 0.03412

R_{eff} = Recovery efficiency factor
= 1.26²⁶

$\% \text{Natural Gas}_{\text{DHW}}$ = Percentage of DHW savings assumed to be Natural Gas

DHW fuel	$\% \text{Natural Gas}_{\text{DHW}}$
Electric	0%
Natural Gas	100%
Unknown	62% ²⁷

$\% \text{Gas}_{\text{Dryer}}$ = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	$\% \text{Gas}_{\text{Dryer}}$
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

$$\Delta\text{Water (gallons)} = \text{Capacity} * (\text{IWF}_{\text{base}} - \text{IWF}_{\text{eff}}) * \text{Ncycles}$$

Where

$\Delta\text{Water (gallons)}$ = Water saved, in gallons

IWF_{base} = Integrated Water Factor of baseline clothes washer
= 5.29²⁹

IWF_{eff} = 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

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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 years³¹.

DEEMED MEASURE COST

The incremental cost for an ENERGY STAR unit is assumed to be \$9.52³² and for an ENERGY STAR Most Efficient unit is \$75³³.

LOADSHAPE

Loadshape R12 - Residential - Dehumidifier

COINCIDENCE FACTOR

The coincidence factor is assumed to be 37%³⁴.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta \text{kWh} = (((\text{Avg Capacity} * 0.473) / 24) * \text{Hours}) * (1 / (\text{L/kWh}_{\text{Base}}) - 1 / (\text{L/kWh}_{\text{Eff}}))$$

Where:

Avg Capacity	= Average capacity of the unit (pints/day) = Actual, if unknown assume capacity in each capacity range as provided in table below, or if capacity range unknown assume average.
0.473	= Constant to convert Pints to Liters
24	= Constant to convert Liters/day to Liters/hour
Hours	= Run hours per year = 1632 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%

Capacity (pints/day) Range	Annual Summer Peak kW Savings		
	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 (≥ 8 place settings + six serving pieces)	270	3.5
Standard with Connected Functionality ³⁹	283	
Compact (< 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 years⁴⁰.

DEEMED MEASURE COST

The incremental cost⁴¹ 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**

$$\Delta \text{kWh}^{43} = ((\text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}) * (\% \text{kWh}_{\text{op}} + (\% \text{kWh}_{\text{heat}} * \% \text{Electric_DHW})))$$

Where:

kWh_{BASE} = Baseline kWh consumption per year

Dishwasher Type	Maximum kWh/year
Standard	307
Compact	222

$\text{kWh}_{\text{ESTAR}}$ = ENERGY STAR kWh annual consumption

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

$\% \text{kWh}_{\text{op}}$ = Percentage of dishwasher energy consumption used for unit operation
 = $1 - 56\%$ ⁴⁴
 = 44%

$\% \text{kWh}_{\text{heat}}$ = Percentage of dishwasher energy consumption used for water heating
 = 56% ⁴⁵

$\% \text{Electric_DHW}$ = Percentage of DHW savings assumed to be electric

DHW fuel	$\% \text{Electric_DHW}$
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	Δ kWh		
	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.

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

Where

$$E_{\text{water total}} = \text{IL Total Water Energy Factor (kWh/Million Gallons)} \\ = 5,010^{47}$$

Using defaults provided:

$$\begin{aligned} \text{Standard } \Delta \text{kWh}_{\text{water}} &= 252/1,000,000 * 5,010 \\ &= 1.3 \text{ kWh} \\ \text{Compact } \Delta \text{kWh}_{\text{water}} &= 67/1,000,000 * 5,010 \\ &= 0.3 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS⁴⁸

$$\Delta \text{kW} = \Delta \text{kWh/Hours} * \text{CF}$$

Where:

$$\Delta \text{kWh} = \text{Annual kWh savings from measure as calculated above. Note do not include the secondary savings in this calculation.}$$

$$\begin{aligned} \text{Hours} &= \text{Annual operating hours}^{49} \\ &= 353 \text{ hours} \end{aligned}$$

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

$$\Delta \text{Therm} = (kWh_{\text{Base}} - kWh_{\text{ESTAR}}) * \%kWh_{\text{heat}} * \% \text{Natural Gas_DHW} * R_{\text{eff}} * 0.03412$$

Where

$\%kWh_{\text{heat}}$ = % of dishwasher energy used for water heating
= 56%

$\% \text{Natural Gas_DHW}$ = Percentage of DHW savings assumed to be Natural Gas

DHW fuel	$\% \text{Natural Gas_DHW}$
Electric	0%
Natural Gas	100%
Unknown	84% ⁵¹

R_{eff} = Recovery efficiency factor
= 1.26⁵²

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

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

Where

$\text{Water}_{\text{Base}}$ = water consumption of conventional unit

Dishwasher Type	$\text{Water}_{\text{Base}}$ (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 $1.73 \times \text{Total Volume}$):

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	$5.57 \times \text{AV} + 193.7$	$5.01 \times \text{AV} + 174.3$
Upright Freezers with Automatic Defrost	7.75 or greater	$8.62 \times \text{AV} + 228.3$	$7.76 \times \text{AV} + 205.5$
Chest Freezers and all other Freezers except Compact Freezers	7.75 or greater	$7.29 \times \text{AV} + 107.8$	$6.56 \times \text{AV} + 97.0$
Compact Upright Freezers with Manual Defrost	< 7.75 and 36 inches or less in height	$8.65 \times \text{AV} + 225.7$	$7.79 \times \text{AV} + 203.1$
Compact Upright Freezers with Automatic Defrost	< 7.75 and 36 inches or less in height	$10.17 \times \text{AV} + 351.9$	$9.15 \times \text{AV} + 316.7$
Compact Chest Freezers	< 7.75 and 36 inches or less in height	$9.25 \times \text{AV} + 136.8$	$8.33 \times \text{AV} + 123.1$

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 years⁵⁷.

DEEMED MEASURE COST

The incremental cost for this measure is \$35⁵⁸.

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:**

$$\Delta \text{kWh} = \text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}$$

Where:

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

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

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

$$\begin{aligned} \Delta \text{kWh} &= (5.57 * (7.75 * 1.73) + 193.7) - (5.01 * (7.75 * 1.73) + 174.3) \\ &= 268.4 - 241.5 \\ &= 26.9 \text{ kWh} \end{aligned}$$

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 ft³ 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

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

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:

$$\begin{aligned}\Delta kW &= 26.9 / 5890 * 0.95 \\ &= 0.0043 \text{ kW}\end{aligned}$$

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:

- Time of Sale: the purchase and installation of a new refrigerator meeting either ENERGY STAR or CEE TIER 2 specifications.
- 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 $\geq 10\%$ or $\geq 15\%$ 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 years⁶⁶

DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be \$40⁶⁷ for an ENERGY STAR unit and \$140⁶⁸ 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 unit⁶⁹.

The avoided replacement cost (after 4 years) of a baseline replacement refrigerator is \$413⁷⁰. 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.

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 25.8⁷¹:

Assumptions after standard changes on September 1st, 2014:

Product Category	Existing Unit UEC_{EXIST} 72	New Baseline UEC_{BASE}	New Efficient UEC_{EE}		Early Replacement (1 st 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 ft³ fresh volume and 6.76 ft³ 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 (1 st 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
= 1.25⁷³

LSAF = Load Shape Adjustment Factor
= 1.057⁷⁴

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 Δ kW			
	Early Replacement (1 st 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 years⁷⁹.

Remaining life of existing equipment is assumed to be 4 years⁸⁰

DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be \$40 for a ENERGY STAR unit⁸¹.

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 unit⁸².

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 0.3⁸⁴.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

Time of Sale: $\Delta kWh = (FLH_{RoomAC} * Btu/H * (1/CEER_{base} - 1/CEER_{ee}))/1000$

Early Replacment:

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

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

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 location⁸⁵:

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/hr⁸⁷

EER_{exist} = Efficiency of existing unit

= Actual. If unknown assume 7.7⁸⁸

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

CEER_{base} = Combined Energy Efficiency Ratio of baseline unit

= As provided in tables above

CEER_{ee} = 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:

$$\Delta \text{kWh}_{\text{ENERGY STAR}} = (248 * 8500 * (1/10.9 - 1/12.0)) / 1000$$

$$= 17.7 \text{ kWh}$$

Early Replacement:

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

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

$$= 137.3 \text{ kWh}$$

$$\Delta \text{kWh for remaining measure life (next 8 years)} = (319 * 9000 * (1/10.9 - 1/12.0))/1000$$

$$= 24.1 \text{ kWh}$$

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: $\Delta kW = \text{Btu/H} * ((1/(\text{CEER}_{\text{base}} * 1.01) - 1/(\text{CEER}_{\text{ee}} * 1.01)))/1000) * CF$

Early Replacement: $\Delta kW = \text{Btu/H} * ((1/\text{EER}_{\text{exist}} - 1/(\text{CEER}_{\text{ee}} * 1.01)))/1000) * CF$

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.3⁹⁰

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:

$$\begin{aligned}\Delta kW_{\text{CEE TIER 1}} &= (8500 * (1/(10.9 * 1.01) - 1/(12.0 * 1.01))) / 1000 * 0.3 \\ &= 0.021 \text{ kW}\end{aligned}$$

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:

$$\begin{aligned}\Delta kW \text{ for remaining life of existing unit (1}^{\text{st}} \text{ 4 years)} &= (9000 * (1/7.7 - 1/(12.0 * 1.01)))/1000 * 0.3 \\ &= 0.128 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW \text{ for remaining measure life (next 8 years)} &= (9000 * (1/(10.9 * 1.01) - 1/(12.0 * 1.01)))/1000 * 0.3 \\ &= 0.022 \text{ kW}\end{aligned}$$

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 \$170⁹³ 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 determine 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 SAVINGS⁹⁴**

Refrigerators:

Energy savings for refrigerators are based upon a linear regression model using the following coefficients⁹⁵:

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

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

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

Primary Usage = Primary Usage Type (in absence of the program) dummy
(= 1 if Primary, else 0)

Interaction: Located in Unconditioned Space x CDD/365.25

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

CDD = Cooling Degree Days

= Dependent on location⁹⁶:

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 used⁹⁸. For illustration purposes, this example uses 0.93.⁹⁹

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

$$\begin{aligned}
 \Delta \text{kWh} &= [83.32 + (22.81 * 3.68) + (0.45 * 485.04) + (18.82 * 27.15) + (0.17 * 406.78) \\
 &\quad + (0.34 * 161.86) + (1.29 * 15.37) + (6.49 * -11.07)] * 0.93 \\
 &= 969 * 0.93 \\
 &= 900.9 \text{ kWh}
 \end{aligned}$$

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients¹⁰⁰:

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

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

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

Interaction: Located in Unconditioned Space x CDD/365.25

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

CDD = Cooling Degree Days (see table above)

Interaction: Located in Unconditioned Space x HDD/365.25

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

HDD = Heating Degree Days (see table above)

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used¹⁰¹. For illustration purposes, the example uses 0.85.¹⁰²

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

$$\begin{aligned} \Delta \text{kWh} &= [132.12 + (26.92 * 12.13) + (0.6 * 156.18) + (15.9 * 31.84) + (0.48 * -19.71) \\ &\quad + (6.61 * 9.78) + (1.3 * -12.75)] * 0.825 \\ &= 977 * 0.825 \\ &= 905 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \text{kWh}/8766 * \text{CF}$$

Where:

kWh = Savings provided in algorithm above

CF = Coincident factor defined as summer kW/average kW

= 1.081 for Refrigerators

= 1.028 for Freezers¹⁰³

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 Illinois 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:

$$\begin{aligned}\Delta kW &= 806/8766 * 1.081 \\ &= 0.099 \text{ kW}\end{aligned}$$

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 years¹⁰⁴.

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

$$\Delta \text{kWh} = ((\text{FLH}_{\text{RoomAC}} * \text{Btu/hr} * (1/\text{EER}_{\text{exist}}))/1000)$$

Where:

$\text{FLH}_{\text{RoomAC}}$ = Full Load Hours of room air conditioning unit
= dependent on location¹⁰⁶;

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
 EER_{exist} = Efficiency of existing unit
 = 9.8¹⁰⁹

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

$$\Delta \text{kWh} = ((319 * 8500 * (1/9.8)) / 1000)$$

$$= 276 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = (\text{Btu/hr} * (1/\text{EER}_{\text{exist}})) / 1000 * \text{CF}$$

Where:

CF = Summer Peak Coincidence Factor for measure
 = 0.3¹¹⁰

For example an 8500 Btu/h unit:

$$\Delta \text{kW} = (8500 * (1/9.8)) / 1000 * 0.3$$

$$= 0.26 \text{ kW}$$

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 dryers¹¹¹. 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 years¹¹².

DEEMED MEASURE COST

The incremental cost for an ENERGY STAR clothes dryer is assumed to be \$152¹¹³

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**

$$\Delta \text{kWh} = (\text{Load}/\text{CEF}_{\text{base}} - \text{Load}/\text{CEF}_{\text{eff}}) * \text{Ncycles} * \% \text{Electric}$$

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

CEF_{base} = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis¹¹⁶. If product class unknown, assume electric, standard.

Product Class	CEF (lbs/kWh)
Vented Electric, Standard ($\geq 4.4 \text{ ft}^3$)	3.11
Vented Electric, Compact (120V) ($< 4.4 \text{ ft}^3$)	3.01
Vented Electric, Compact (240V) ($< 4.4 \text{ ft}^3$)	2.73
Ventless Electric, Compact (240V) ($< 4.4 \text{ ft}^3$)	2.13
Vented Gas	2.84 ¹¹⁷

CEF_{eff} = 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 ($\geq 4.4 \text{ ft}^3$)	3.93
Vented or Ventless Electric, Compact (120V) ($< 4.4 \text{ ft}^3$)	3.80
Vented Electric, Compact (240V) ($< 4.4 \text{ ft}^3$)	3.45
Ventless Electric, Compact (240V) ($< 4.4 \text{ ft}^3$)	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 dryers¹²¹

Example

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

$$\begin{aligned}\Delta\text{kWh} &= ((8.45/3.11 - 8.45/3.93) * 283 * 100\%) \\ &= 160 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = \Delta\text{kWh}/\text{Hours} * \text{CF}$$

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

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

$$\begin{aligned}\Delta\text{kW} &= 160/283 * 3.8\% \\ &= 0.0215 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

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

$$\Delta\text{Therm} = (\text{Load}/\text{EF}_{\text{base}} - \text{Load}/\text{CE}_{\text{eff}}) * \text{Ncycles} * \text{Therm}_{\text{convert}} * \% \text{Gas}$$

Where:

$\text{Therm}_{\text{convert}}$ = Conversion factor from kWh to Therm
= 0.03412

$\% \text{Gas}$ = Percent of overall savings coming from gas
= 0% for electric units and 84% for gas units¹²⁴

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:

$$\begin{aligned}\Delta\text{Therm} &= (8.45/2.84 - 8.45/3.48) * 283 * 0.03412 * 0.84 \\ &= 4.44 \text{ therms}\end{aligned}$$

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 years¹²⁵.

DEEMED MEASURE COST

The incremental cost for this measure is estimated at \$17¹²⁶.

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

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

Where:

kWh_{base} = Daily energy use (kWh/day) for baseline water cooler¹²⁷

Type of Water Cooler	kWh _{base}
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 cooler¹²⁸

Type of Water Cooler	kWh_{ee}
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 days¹²⁹

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

ΔkW = $\Delta kWh / \text{Hours} * CF$

Where:

Hours = Number of hours per year water cooler is in use
= 8766 hours¹³⁰

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 (O₃), 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 system¹³²

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**

$$\Delta \text{kWh} = \text{kWh}_{\text{HotWash}} * (\% \text{HotWash}_{\text{base}} - \% \text{HotWash}_{\text{Ozone}})$$

Where:

$$\text{kWh}_{\text{HotWash}} = (\% \text{ElectricDHW} * \text{Capacity} * \text{IWF} * \% \text{HotWater} * (T_{\text{OUT}} - T_{\text{IN}}) * 8.33 * 1.0 * \text{Ncycles}) / (\text{RE}_{\text{electric}} * 3.412)$$

$\% \text{ElectricDHW}$ = Proportion of water heating supplied by electric heating

DHW fuel	$\% \text{FossilDHW}$
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/ft³).

= Actual. If unknown, use the following values:

Efficiency Level	IWF (gallons/cycle/ft ³)	
	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

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

= 0.1757¹³⁶

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 Residential 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.

	$= 54.1^{\circ}\text{F}^{137}$
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.

$$\Delta\text{kWh} = (1 * 4.96 * 8.4 * 0.1757 * (125 - 54.1) * 8.33 * 1.0 * 264) / (0.98 * 3412) * (0.7743 - 0)$$

$$= 264 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = \Delta\text{kWh}/\text{Hours} * \text{CF}$$

Where:

ΔkWh	= Energy Savings as calculated above
Hours	= Assumed Run hours of Clothes Washer
	$= 264 \text{ hours}^{141}$
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.

$$\Delta\text{kW} = 264/264 * 0.038$$

$$= 0.038\text{kW}$$

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

$$\Delta \text{Therm} = \text{ThermHotWash} * (\% \text{HotWash}_{\text{base}} - \% \text{HotWash}_{\text{Ozone}})$$

Where:

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

$\% \text{FossilDHW}$ = proportion of water heating supplied by natural gas heating

DHW fuel	$\% \text{FossilDHW}$
Electric	0%
Natural gas	100%
Unknown	84% ¹⁴³

RE_{gas} = Recovery efficiency of gas water heater

= 78% For SF homes¹⁴⁴

= 67% For MF homes¹⁴⁵

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.

$$\Delta \text{Therms} = (1 * 4.96 * 8.4 * 0.1757 * (125 - 54.1) * 8.33 * 1.0 * 264) / (0.78 * 100,000) * (0.7743 - 0) \\ = 11.32 \text{ Therms}$$

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).

$$\text{Detergent savings per year} = \text{Detergent}_{\text{cost}} * \text{Ncycles}$$

Where:

$\text{Detergent}_{\text{cost}}$ = 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.

Detergent savings per year = $0.16 * 295$

$$= \$47.2$$

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 years¹⁴⁷.

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 \$10¹⁴⁸.

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**

$$\Delta \text{kWh} = \text{kWh} * \text{ISR}$$

Where:

kWh = Assumed annual kWh savings per unit
 = 56.5 kWh for 5-plug units or 103 kWh for 7-plug units¹⁵⁰

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

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} * \text{CF}$$

Where:

Hours = Annual number of hours during which the controlled standby loads are turned off by the Tier 1 Advanced power Strip.
 = 7,129¹⁵³

CF = Summer Peak Coincidence Factor for measure

¹⁵⁰ NYSEDA 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; NYSEDA 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 devices¹⁵⁶. 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 television¹⁵⁷.

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

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 years¹⁵⁸.

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

$$\Delta \text{kWh} = \text{ERP} * \text{BaselineEnergy}_{\text{AV}} * \text{ISR}$$

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%

$$\text{BaselineEnergy}_{AV} = 432 \text{ kWh}^{160}$$

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

ΔkWh = Energy savings as calculated above

Hours = Annual number of hours during which the APS provides savings.
= 4,380¹⁶¹

CF = Summer Peak Coincidence Factor for measure
= 0.8¹⁶²

NATURAL GAS SAVINGS

N/A¹⁶³

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

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 ($\leq 65,000$ 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 ($\leq 65,000$ Btu/hr) air source heat pump with specifications to be determined by program.

DEFINITION OF BASELINE EQUIPMENT

A new residential sized ($\leq 65,000$ 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 years¹⁶⁷ 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 unit¹⁶⁸.

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 capacity¹⁷⁰. 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 \$150¹⁷¹.

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 _{SPP, 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 _{SPP, 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:

$$\Delta kWh = ((FLH_{cooling} * Capacity_{cooling} * (1/(SEER_{base} * (1 - DeratingCool_{Base}))) - 1/(SEER_{ee} * SEER_{adj} * (1 - DeratingCool_{Eff})))) / 1000) + ((FLH_{heat} * Capacity_{heating} * (1/(HSPF_{base} * (1 - DeratingHeat_{Base}))) - 1/(HSPF_{ee} * HSPF_{adj} * (1 - DeratingHeat_{Eff})))) / 1000)$$

Early replacement¹⁷⁵:

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

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

$$= ((\text{FLH}_{\text{cooling}} * \text{Capacity}_{\text{cooling}} * (1/(\text{SEER}_{\text{exist}} * (1 - \text{DeratingCool}_{\text{Base}}))) - 1/(\text{SEER}_{\text{ee}} * \text{SEER}_{\text{adj}} * (1 - \text{DeratingCool}_{\text{Eff}})))) / 1000) + ((\text{FLH}_{\text{heat}} * \text{Capacity}_{\text{heating}} * (1/(\text{HSPF}_{\text{exist}} * (1 - \text{DeratingHeat}_{\text{Base}}))) - 1/(\text{HSPF}_{\text{ee}} * \text{HSPF}_{\text{adj}} * (1 - \text{DeratingHeat}_{\text{Eff}})))) / 1000)$$

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

$$= ((\text{FLH}_{\text{cooling}} * \text{Capacity}_{\text{cooling}} * (1/(\text{SEER}_{\text{base}} * (1 - \text{DeratingCool}_{\text{Base}}))) - 1/(\text{SEER}_{\text{ee}} * \text{SEER}_{\text{adj}} * (1 - \text{DeratingCool}_{\text{Eff}})))) / 1000) + ((\text{FLH}_{\text{heat}} * \text{Capacity}_{\text{heating}} * (1/(\text{HSPF}_{\text{base}} * (1 - \text{DeratingHeat}_{\text{Base}}))) - 1/(\text{HSPF}_{\text{ee}} * \text{HSPF}_{\text{adj}} * (1 - \text{DeratingHeat}_{\text{Eff}})))) / 1000)$$

Where:

$\text{FLH}_{\text{cooling}}$ = Full load hours of air conditioning
= dependent on location:

Climate Zone (City based upon)	$\text{FLH}_{\text{cooling}}$ (single family) ¹⁷⁶	$\text{FLH}_{\text{cooling}}$ (general multifamily) ¹⁷⁷	$\text{FLH}_{\text{cooling}}$ (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

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

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

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

= Use actual SEER rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year to account for degradation over time¹⁸⁰, or use defaults provided below:

Existing Cooling System	$\text{SEER}_{\text{exist}}$ 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)
= 14¹⁸³

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

DeratingCool_{Eff} = Efficient ASHP Cooling derating
= 0% if Quality Installation is performed
= 10% if Quality Installation is not performed or unknown¹⁸⁵

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 Factor¹⁸⁹ 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)

= 8.2¹⁹²

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

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

DeratingHeatEff = Efficient ASHP Heating derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed¹⁹⁴

DeratingHeatBase = Baseline Heating 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;

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

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

$$\begin{aligned} \Delta kWh &= ((903 * 34,800 * (1/(14 * (1 - 0.1)) - 1/(15 * 1.011 * (1 - 0)))) / 1000) + ((1,288 * 33,000 * (1/(8.2 * (1 - 0.1)) - 1/(9 * 1.001 * (1 - 0)))) / 1000) \\ &= 1463 \text{ kWh} \end{aligned}$$

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):

$$\begin{aligned} &= ((903 * 34,800 * (1/(9.3 * (1 - 0.1)) - 1/(15 * 1.011 * (1 - 0)))) / 1000) + ((1,288 * 33,000 * (1/(5.54 * (1 - 0.1)) - 1/(9 * 1.001 * (1 - 0)))) / 1000) \\ &= 5489 \text{ kWh} \end{aligned}$$

ΔkWh for remaining measure life (next 12 years):

$$\begin{aligned} &= ((903 * 34,800 * (1/(14 * (1 - 0.1)) - 1/(15 * 1.011 * (1 - 0)))) / 1000) + ((1,288 * 33,000 * (1/(8.2 * (1 - 0.1)) - 1/(9 * 1.001 * (1 - 0)))) / 1000) \\ &= 1463 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS**Time of sale:**

$$\Delta kW = (\text{Capacity_cooling} * (1/(\text{EER_base} * (1 - \text{DeratingCool}_{\text{Base}})) - 1/(\text{EER_ee} * (1 - \text{DeratingCool}_{\text{Eff}})))) / 1000 * CF$$

Early replacement¹⁹⁵:

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

$$= (\text{Capacity_cooling} * (1/(\text{EER}_{\text{exist}} * (1 - \text{DeratingCool}_{\text{Base}})) - 1/(\text{EER}_{\text{ee}} * (1 - \text{DeratingCool}_{\text{Eff}})))) / 1000 * CF$$

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

$$= (\text{Capacity_cooling} * (1/(\text{EER_base} * (1 - \text{DeratingCool}_{\text{Base}})) - 1/(\text{EER_ee} * (1 - \text{DeratingCool}_{\text{Eff}})))) / 1000 * CF$$

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 time¹⁹⁶, 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)
= 11¹⁹⁹

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

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:

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

$$= 0.458 \text{ kW}$$

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

$$= 0.297 \text{ kW}$$

Early Replacement:

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

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

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

$$= 1.68 \text{ kW}$$

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

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

$$= 0.458 \text{ kW}$$

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

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

$$= 1.087 \text{ kW}$$

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

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

$$= 0.297 \text{ kW}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ASHP-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 years²⁰³.

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 13 years²⁰⁴. See section below for detail.

DEEMED MEASURE COST

The measure cost including material and installation is assumed to be \$3 per linear foot²⁰⁵.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta \text{Therm} = (((1/R_{\text{exist}} * C_{\text{exist}}) - (1/R_{\text{new}} * C_{\text{new}})) * \text{FLH_heat} * L * \Delta T) / \eta_{\text{Boiler}} / 100,000$$

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) $[(hr \cdot ^\circ F \cdot ft^2)/Btu]$
 $= 0.5^{206}$

R_{new} = Pipe heat loss coefficient of insulated pipe (new) $[(hr \cdot ^\circ F \cdot ft^2)/Btu]$
 $= \text{Actual } (0.5 + R \text{ value of insulation})$

FLH_{heat} = Full load hours of heating
 $= \text{Dependent on location}^{207}$:

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)
 $= \text{Actual}$

C_{exist} = Circumference of bare pipe (ft) (Diameter (in) $\cdot \pi/12$)
 $= \text{Actual } (0.5'' \text{ pipe} = 0.131\text{ft}, 0.75'' \text{ pipe} = 0.196\text{ft})$

C_{new} = Circumference of pipe with insulation (ft) $([Diameter \text{ of pipe (in)}] + ([Thickness \text{ of Insulation (in)}] \cdot 2)) \cdot \pi/12$
 $= \text{Actual}$

ΔT = Average temperature difference between circulated heated water and unconditioned space air temperature ($^\circ F$)²⁰⁹

Pipes in unconditioned basement:

Outdoor reset controls	ΔT ($^\circ F$)
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 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.

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

$$\eta_{\text{Boiler}} = \text{Efficiency of boiler}$$

$$= 0.819^{211}$$

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:

$$\Delta \text{Therm} = (((1/0.5 * 0.196) - (1/3.5 * 0.589)) * 10 * 120 * 1288) / 0.819 / 100,067$$

$$= 4.2 \text{ therms}$$

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
η_{Heat}	Boiler	82% AFUE

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 13 years²¹².

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 ($\leq 65,000$ 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 unknown²¹⁴.

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 furnaces. The unit (furnace or CAC unit) that initially caused the customer to contact a trade ally is defined as the "primary unit". The furnace or CAC unit that was also replaced but did not initially prompt the customer to contact a trade ally is defined as the "secondary unit". This evaluation used different criteria for early replacement due to the availability of data after the fact; cost of any repairs $< \$550$ and age of unit < 20 years. Report presented to Nicor Gas Company February 27, 2014.

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 above²¹⁵ for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years²¹⁶.

Remaining life of existing equipment is assumed to be 6 years²¹⁷.

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below²¹⁸:

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 below²¹⁹.

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

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.

\$3,140²²⁰. 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 \$150²²¹.

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:

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

Early replacement²²⁴:

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

$$=(\text{FLHcool} * \text{Capacity} * (1/(\text{SEERexist} * (1 - \text{DeratingCool}_{\text{Base}})) - 1/(\text{SEERee} * \text{SEERadj} * (1 - \text{DeratingCool}_{\text{Eff}}))))/1000$$

ΔkWH for remaining measure life (next 12 years):

$$= (\text{FLHcool} * \text{Capacity} * (1/(\text{SEERbase} * (1 - \text{DeratingCool}_{\text{Base}})) - 1/(\text{SEERee} * \text{SEERadj} * (1 - \text{DeratingCool}_{\text{Eff}}))))/1000$$

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 type²²⁵:

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 homes²²⁸. If building type is unknown, assume 31,864Btu/hr²²⁹.

SEERbase = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh)
= 13²³⁰

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 time²³¹, or if unknown assume 9.3²³².

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 calculate 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

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

DeratingCool_{Eff} = Efficient Central Air Conditioner Cooling derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown²³⁴

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:

$$\begin{aligned} SEER_{adj} &= (0.805 * (12.5/17) + 0.367) \\ &= 0.959 \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (629 * 36,000 * (1/(13 * (1-0.1)) - 1 / (17 * 0.959 * (1-0.1)))) / 1000 \\ &= 392 kWh \end{aligned}$$

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

$$\begin{aligned} \Delta kWh &= (629 * 36,000 * (1/(13 * (1-0.1)) - 1 / (17 * 0.959 * (1-0)))) / 1000 \\ &= 546 kWh \end{aligned}$$

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:

$$\begin{aligned} \Delta kWh(\text{for first 6 years}) &= (629 * 36,000 * (1/(9.3 * (1-0.1)) - 1/(17 * 0.959 * (1-0))))/1000 \\ &= 1,316 kWh \end{aligned}$$

$$\begin{aligned} \Delta kWh(\text{for next 12 years}) &= (629 * 36,000 * (1/(13 * (1-0.1)) - 1/(17 * 0.959 * (1-0))))/1000 \\ &= 546 kWh \end{aligned}$$

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

$$\Delta kW = (\text{Capacity} * (1/(EER_{base} * (1 - \text{DeratingCool}_{Base})) - 1/(EER_{ee} * (1 - \text{DeratingCool}_{Eff}))))/1000 * CF$$

Early replacement²³⁵:

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

$$= (\text{Capacity} * (1/(EER_{exist} * (1 - \text{DeratingCool}_{Base})) - 1/(EER_{ee} * (1 - \text{DeratingCool}_{Eff}))))/1000 * CF$$

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).

$$= (\text{Capacity} * (1/(\text{EER}_{\text{base}} * (1 - \text{DeratingCool}_{\text{base}})) - 1/(\text{EER}_{\text{ee}} * (1 - \text{DeratingCool}_{\text{eff}}))))/1000 * \text{CF}$$

Where:

EER_{base} = EER Efficiency of baseline unit

$$= 10.5^{236}$$

$\text{EER}_{\text{exist}}$ = 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 time²³⁷. If unknown assume 7.5²³⁸

EER_{ee} = 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:

$$\begin{aligned} \Delta \text{kW}_{\text{SSP}} &= (36,000 * (1/(10.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.68 \\ &= 0.550 \text{ kW} \end{aligned}$$

$$\begin{aligned} \Delta \text{kW}_{\text{PJM}} &= (36,000 * (1/(10.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.466 \\ &= 0.377 \text{ kW} \end{aligned}$$

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

$$\begin{aligned} \Delta \text{kW}_{\text{SSP}} \text{ (for first 6 years)} &= (36,000 * (1/(7.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.68 \\ &= 1.587 \text{ kW} \end{aligned}$$

$$\begin{aligned} \Delta \text{kW}_{\text{SSP}} \text{ (for next 12 years)} &= (36,000 * (1/(10.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.68 \\ &= 0.550 \text{ kW} \end{aligned}$$

$$\begin{aligned} \Delta \text{kW}_{\text{PJM}} \text{ (for first 6 years)} &= (36,000 * (1/(7.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.466 \\ &= 1.087 \text{ kW} \end{aligned}$$

$$\begin{aligned} \Delta \text{kW}_{\text{PJM}} \text{ (for next 12 years)} &= (36,000 * (1/(10.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.466 \\ &= 0.377 \text{ kW} \end{aligned}$$

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 years²⁴².

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years²⁴³. 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 (ΔCFM25_{DL}) = (Pre CFM50_{DL} – Post CFM50_{DL}) * 0.64 * (SLF + RLF)

Where:

0.64 = Converts CFM50 to CFM25²⁴⁶

SLF = Supply Loss Factor

= % leaks sealed located in Supply ducts * 1²⁴⁷

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 = 0.5²⁴⁸

RLF = Return Loss Factor

= % leaks sealed located in Return ducts * 0.5²⁴⁹

Default = 0.25²⁵⁰

c) Calculate Electric Energy Savings:

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

$\Delta kWh_{cooling} = ((\Delta CFM_{25DL} / ((CapacityCool / 12,000) * 400)) * FLH_{cool} * CapacityCool * TRF_{cool}) / 1000 / \eta_{cool}$

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

Where:

ΔCFM_{25DL} = 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 below²⁵²:

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.

TRFcool = Thermal Regain Factor for cooling by space type
 = 1.0 for Unconditioned Spaces
 = 0.4 for Semi-Conditioned Spaces²⁵⁴

1000 = Converts Btu to kBtu

η_{Cool} = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)
 = Actual. If unknown assume the following²⁵⁵:

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

Δ Therms = 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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

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:

$\Delta\text{CFM}_{25\text{DL}}$ = (387 – 139) * 0.64 * (0.5 + 0.25)
= 119 CFM25

Energy Savings:

$\Delta\text{kWh}_{\text{cooling}}$ = $\left[\left(\frac{119}{(36,000/12,000) * 400} \right) * 730 * 36,000 * 1 \right] / 1000 / 11 + (212 * 0.0314 * 29.3)$
= 237 + 195
= 432 kWh

Heating savings for homes with electric heat:

$$\Delta\text{kWh}_{\text{heating}} = ((\Delta\text{CFM}_{25\text{DL}} / ((\text{OutputCapacityHeat} / 12,000) * 400)) * \text{FLH}_{\text{heat}} * \text{OutputCapacityHeat} * \text{TRF}_{\text{heat}}) / \eta_{\text{heat}} / 3412$$

Where:

OutputCapacityHeat = Heating output capacity (Btu/hr) of electric heat
=Actual

FLH_{heat} = Full load heating hours
= Dependent on location as below²⁵⁷:

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 Spaces²⁵⁹

η_{Heat} = Efficiency in COP of Heating equipment
 = Actual. If not available use²⁶⁰:

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:

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

$$= 734 \text{ kWh}$$

Methodology 2: Evaluation of Distribution Efficiency

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute “Distribution Efficiency Look-Up Table”

$$\Delta \text{kWh} = (((DE_{\text{after}} - DE_{\text{before}}) / DE_{\text{after}}) * \text{FLH}_{\text{cool}} * \text{Capacity}_{\text{Cool}} * \text{TRF}_{\text{cool}}) / 1000 / \eta_{\text{Cool}}) + (\Delta \text{Therms} * F_e * 29.3)$$

Where:

DE_{after} = Distribution Efficiency after duct sealing
 DE_{before} = Distribution Efficiency before duct sealing
 FLH_{cool} = Full load cooling hours
 = Dependent on location as below²⁶¹:

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 Spaces²⁶³

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume²⁶⁴:

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:

$$\begin{aligned}\Delta \text{kWh}_{\text{cooling}} &= (((0.92 - 0.85)/0.92) * 730 * 36,000 * 1) / 1000 / 11 + (212 * 0.0314 * 29.3) \\ &= 182 + 195 \\ &= 377 \text{ kWh}\end{aligned}$$

Heating savings for homes with electric heat:

$$\Delta \text{kWh}_{\text{heating}} = ((\text{DE}_{\text{after}} - \text{DE}_{\text{before}}) / \text{DE}_{\text{after}}) * \text{FLHheat} * \text{OutputCapacityHeat} * \text{TRFheat} / \eta_{\text{Heat}}$$

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 below²⁶⁵:

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 Spaces²⁶⁷

COP = Coefficient of Performance of electric heating system²⁶⁸
= Actual. If not available use²⁶⁹:

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:

$$\Delta \text{kWh}_{\text{heating}} = ((0.92 - 0.85)/0.92) * 1,754 * 36,000 * 1) / 2.5) / 3412$$

$$= 563 \text{ kWh}$$

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

$$\Delta kW = \Delta kWh_{cooling} / FLH_{cool} * CF$$

Where:

FLH_{cool} = Full load cooling hours:
= Dependent on location as below²⁷⁰:

Climate Zone (City based upon)	FLH _{cool} Single Family	FLH _{cool} 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

$$\Delta Therm = (((\Delta CFM_{25DL} / (InputCapacityHeat * 0.0123)) * FLH_{heat} * InputCapacityHeat * TRF_{heat} * (\eta_{equipment} / \eta_{system})) / 100,000$$

Where:

ΔCFM_{25DL} = Duct leakage reduction in CFM₂₅

InputCapacityHeat = Heating input capacity (Btu/hr)
=Actual

0.0123 = Conversion of Capacity to CFM (0.0123CFM / Btu/hr)²⁷⁴

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.

FLH_{heat} = Full load heating hours
 =Dependent on location as below²⁷⁵:

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

TRF_{heat} = Thermal Regain Factor for heating by space type
 = 0.40 for Semi-Conditioned Spaces
 = 1.0 for Unconditioned Spaces²⁷⁷

100,000 = Converts Btu to therms

η _{Equipment} = Heating Equipment Efficiency
 = Actual²⁷⁸. If not available use 83%²⁷⁹

η _{System} = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)²⁸⁰
 = Actual. If not available use 70%²⁸¹

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:

$(0.24 \times 0.92) + (0.76 \times 0.8) = 0.829$

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: $0.829 \times (1 - 0.15) = 0.70$

For example, duct sealing in unconditioned space in a house in Springfield with an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following blower door test results:

$$\begin{aligned}
 \text{Before: } CFM_{50\text{Whole House}} &= 4800 \text{ CFM}_{50} \\
 CFM_{50\text{Envelope Only}} &= 4500 \text{ CFM}_{50} \\
 \text{House to duct pressure of 45 Pascals} &= 1.29 \text{ SCF (Energy Conservatory look up table)} \\
 \text{After: } CFM_{50\text{Whole House}} &= 4600 \text{ CFM}_{50} \\
 CFM_{50\text{Envelope Only}} &= 4500 \text{ CFM}_{50} \\
 \text{House to duct pressure of 43 Pascals} &= 1.39 \text{ SCF (Energy Conservatory look up table)} \\
 \text{Duct Leakage:} \\
 CFM_{50\text{DL before}} &= (4800 - 4500) * 1.29 \\
 &= 387 \text{ CFM} \\
 CFM_{50\text{DL after}} &= (4600 - 4500) * 1.39 \\
 &= 119 \text{ CFM} \\
 \text{Duct Leakage reduction at CFM}_{25}: \\
 \Delta CFM_{25\text{DL}} &= (387 - 119) * 0.64 * (0.5 + 0.25) \\
 &= 119 \text{ CFM}_{25} \\
 \text{Energy Savings:} \\
 \text{Pre Distribution Efficiency} &= 1 - (387/4800) = 92\% \\
 \eta_{\text{System}} &= 80\% * 92\% = 74\% \\
 \Delta \text{Therm} &= ((119 / (105,000 * 0.0123)) * 1,754 * 105,000 * 1 * (0.8/0.74)) / 100,000 \\
 &= 183 \text{ therms}
 \end{aligned}$$

Methodology 2: Evaluation of Distribution Efficiency

$$\Delta \text{Therm} = ((DE_{\text{after}} - DE_{\text{before}}) / DE_{\text{after}}) * FLH_{\text{heat}} * \text{InputCapacityHeat} * TRF_{\text{heat}} * (\eta_{\text{Equipment}} / \eta_{\text{System}}) / 100,000$$

Where:

$$\begin{aligned}
 DE_{\text{after}} &= \text{Distribution Efficiency after duct sealing} \\
 DE_{\text{before}} &= \text{Distribution Efficiency before duct sealing} \\
 \text{Other variables as defined above}
 \end{aligned}$$

For example, duct sealing in unconditioned space in a house in Springfield an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following duct evaluation results:

$$\begin{aligned}
 DE_{\text{after}} &= 0.92 \\
 DE_{\text{before}} &= 0.85 \\
 \text{Energy Savings:} \\
 \eta_{\text{System}} &= 80\% * 85\% = 68\% \\
 \Delta \text{Therm} &= (((0.92 - 0.85) / 0.92) * 1,754 * 105,000 * 1 * (0.8/0.68)) / 100,067 \\
 &= 165 \text{ therm}
 \end{aligned}$$

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
η_{Cool}	Central AC	13 SEER
	Heat Pump	14 SEER
η_{Heat}	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 years²⁸².

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 years²⁸³.

DEEMED MEASURE COST

The capital cost for this measure is assumed to be \$97²⁸⁴.

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 study²⁸⁵ 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

$$\Delta \text{kWh} = \text{Capacity_cooling} * \text{kWhSavingsPerTon}$$

Where:

Capacity_cooling = Capacity of cooling system in tons
= Actual (1 ton = 12,000Btu/hr)

kWhSavingsPerTon = Blower fan kWh savings per ton of cooling²⁸⁶

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:

$$\begin{aligned}\Delta kWh &= 3 * 175 \\ &= 525 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \text{Capacity}_{\text{cooling}} * kW_{\text{SavingsPerTon}}$$

Where:

$$kW_{\text{SavingsPerTon}} = \text{Blower fan kW savings per ton of cooling}^{288}$$

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:

$$\begin{aligned}\Delta kW_{ssp} &= 3 * 0.006 \\ &= 0.018 kW \\ \Delta kW_{pjm} &= 3 * 0.010 \\ &= 0.030 kW\end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta \text{therms}^{290} = - \text{HeatingkWhSavings} * 0.03412 / \text{AFUE}$$

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 cooling²⁹¹

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:

Δ therms = $(-39 \text{ kWh} * 3 \text{ tons} * 0.03412) / 0.95$

Δ therms = - 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 $\leq 75\%$, 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 unknown²⁹⁵.

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 years²⁹⁶.

Early replacement: Remaining life of existing equipment is assumed to be 8 years²⁹⁷.

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is dependent on tier²⁹⁸:

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 \$4,045²⁹⁹. 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:

$$\Delta\text{Therms} = (\text{EFLH} * \text{CAPInput} * (\text{AFUE}(\text{eff}) / \text{AFUE}(\text{base}) - 1)) / 100000$$

Early replacement³⁰⁰: ΔTherms for remaining life of existing unit (1st 8 years):

$$= (\text{EFLH} * \text{CAPInput} * (\text{AFUE}(\text{eff}) / \text{AFUE}(\text{exist}) - 1)) / 100000$$

 ΔTherms for remaining measure life (next 17 years):

$$= (\text{EFLH} * \text{CAPInput} * (\text{AFUE}(\text{eff}) / \text{AFUE}(\text{base}) - 1)) / 100000$$

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) = Efficient Boiler Annual Fuel Utilization Efficiency Rating

= Actual. If unknown, use defaults dependent³⁰⁴ 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

$$\begin{aligned}\Delta\text{Therms} &= (836 * 100000 * (0.90/0.82 - 1)) / 100000 \\ &= 81.6 \text{ Therms}\end{aligned}$$

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.

$$\begin{aligned}\Delta\text{Therms for remaining life of existing unit (1st 8 years):} \\ &= (836 * 100000 * (0.90/0.616 - 1)) / 100000 \\ &= 385.4 \text{ Therms}\end{aligned}$$

$$\begin{aligned}\Delta\text{Therms for remaining measure life (next 17 years):} \\ &= (836 * 100000 * (0.90/0.82 - 1)) / 100000 \\ &= 81.6 \text{ Therms}\end{aligned}$$

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 $\leq 75\%$, 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 unknown³⁰⁶.

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 furnaces. The unit (furnace or CAC unit) that initially caused the customer to contact a trade ally is defined as the "primary unit". The furnace or CAC unit that was also replaced but did not initially prompt the customer to contact a trade ally is defined as the "secondary unit". This evaluation used different criteria for early replacement due to the availability of data after the fact; cost of any repairs < \$550 and age of unit < 20 years. Report presented to Nicor Gas Company February 27, 2014.

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 years³⁰⁷.

For early replacement: Remaining life of existing equipment is assumed to be 6 years³⁰⁸.

DEEMED MEASURE COST

Time of sale: The incremental installed cost (retail equipment cost plus installation cost) for this measure depends on efficiency as listed below³⁰⁹:

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 \$2903³¹⁰. 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 replacement³¹¹:

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

$$= \frac{\frac{EFLH * CAPInput}{(1 - Derating_{eff})} * \left(\frac{AFUE(eff) * (1 - Derating(eff))}{AFUE(exist) * (1 - Derating(base))} - 1 \right)}{100,000}$$

$\Delta Therms$ 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 below³¹⁵:

Program Year	AFUE(base)
Time of Sale	80%
Early Replacement ³¹⁶	90%

AFUE(eff) = Efficient Furnace Annual Fuel Utilization Efficiency Rating
 = Actual. If unknown, assume 95%³¹⁷

Derating(base) = Baseline furnace AFUE derating
 = 6.4%³¹⁸

Derating(eff) = Efficient furnace AFUE derating
 = 0% if verified quality installation is performed
 = 6.4% if verified quality installation is not performed or unknown³¹⁹

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:

$$\Delta \text{Therms} = ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.8 * (1-0.064))) - 1)) / 100067$$

$$= 220 \text{ therms}$$

For example, a 95% AFUE, 80,000Btuh furnace purchased and installed without verified quality installation for an existing home near Rockford:

$$\Delta \text{Therms} = ((1022 * 80,000)/(1-0.064) * (((0.95 * (1-0.064)) / (0.8 * (1-0.064))) - 1)) / 100067$$

$$= 164 \text{ therms}$$

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:

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

$$= ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.644 * (1-0.064))) - 1)) / 100067$$

$$= 471 \text{ therms}$$

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

$$= ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.9 * (1-0.064))) - 1)) / 100067$$

$$= 104 \text{ therms}$$

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 than³²⁰:

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 11.8³²¹ 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; $0.6483 - (0.0017 * \text{storage capacity in gallons})$ for tanks ≤ 55 gallons and $0.7897 - (0.0004 * \text{storage capacity in gallons})$ 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: $(-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$ Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

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 years³²³.

For early replacement, the remaining life of existing equipment is assumed to be 8 years³²⁴.

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 ton³²⁵), minus the assumed installation cost of the baseline equipment (\$1381 per ton for ASHP³²⁶ or \$2011 for a new baseline 80% AFUE furnace or \$3543 for a new 82% AFUE boiler³²⁷ and \$952 per ton³²⁸ 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 replacement³²⁹. 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.

$$\begin{aligned} CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)} \\ &= 72\%^{331} \\ CF_{PJM} &= \text{PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)} \\ &= 46.6\%^{332} \end{aligned}$$

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

$$\begin{aligned} \Delta kWh &= [\text{Cooling savings}] + [\text{Heating savings}] + [\text{DHW savings}] \\ &= [\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{ElecHeat} * \text{FLHheat} * \\ &\quad \text{Capacity_heating} * (1/\text{HSPF}_{\text{base}} - 1/(\text{COP}_{\text{PL}} * 3.412))/1000] + [\text{ElecDHW} * \% \text{DHWDisplaced} \\ &\quad * ((1/\text{EF}_{\text{ELEC}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)] \end{aligned}$$

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

If measure is supported by gas utility only, $\Delta kWh = 0$

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

$$\begin{aligned} \Delta kWh &= [\text{Cooling savings}] + [\text{Heating savings from base ASHP to GSHP}] + [\text{DHW savings}] \\ &= [\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{FLHheat} * \\ &\quad \text{Capacity_heating} * (1/\text{HSPF}_{\text{ASHP}} - 1/(\text{COP}_{\text{PL}} * 3.412))/1000] + [\text{ElecDHW} * \% \text{DHWDisplaced} \\ &\quad * ((1/\text{EF}_{\text{ELEC}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)] \end{aligned}$$

Early replacement (non-fuel switch only)³³³:

$$\begin{aligned} \Delta kWh \text{ for remaining life of existing unit (1st 8 years):} \\ &= [\text{Cooling savings}] + [\text{Heating savings}] + [\text{DHW savings}] \\ &= [\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{exist}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{ElecHeat} * \text{FLHheat} * \\ &\quad \text{Capacity_heating} * (1/\text{HSPF}_{\text{exist}} - 1/(\text{COP}_{\text{PL}} * 3.412))/1000] + [\text{ElecDHW} * \\ &\quad \% \text{DHWDisplaced} * ((1/\text{EF}_{\text{ELEC}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / \\ &\quad 3412)] \end{aligned}$$

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).

Δ kWh for remaining measure life (next 17 years):

$$= [\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{ElecHeat} * \text{FLHheat} * \text{Capacity_heating} * (1/\text{HSPF}_{\text{base}} - 1/(\text{COP}_{\text{PL}} * 3.412))/1000] + [\text{ElecDHW} * \% \text{DHWDisplaced} * ((1/\text{EF}_{\text{ELEC}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)]$$

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

If measure is supported by gas utility only, Δ kWh = 0

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

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

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

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

Δ kWh for remaining measure life (next 17 years):

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

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

Where:

FLHcool = Full load cooling hours

Dependent on location as below³³⁴:

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 were 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.

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

Existing Cooling System	SEER _{base}
Air Source Heat Pump	14 ³³⁷
Central AC	13 ³³⁸
No central cooling	13 ³³⁹

SEER_{exist} = SEER Efficiency of existing cooling unit

= Use actual SEER rating where it is possible to measure or reasonably estimate, if unknown assume default provided below:

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)

= 14³⁴⁴

EER_{PL} = Part Load EER Efficiency of efficient GSHP unit³⁴⁵

= Actual installed

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

FLH_{heat} = Full load heating hours

Dependent on location as below³⁴⁶:

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)
= 8.2³⁵¹

COP_{PL} = Part Load Coefficient of Performance of efficient unit³⁵²
= 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

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								
	<table border="1"> <thead> <tr> <th>Household Unit Type</th><th>Household</th></tr> </thead> <tbody> <tr> <td>Single-Family - Deemed</td><td>2.56³⁵⁶</td></tr> <tr> <td>Multifamily - Deemed</td><td>2.1³⁵⁷</td></tr> <tr> <td>Custom</td><td>Actual Occupancy or Number of Bedrooms³⁵⁸</td></tr> </tbody> </table>	Household Unit Type	Household	Single-Family - Deemed	2.56 ³⁵⁶	Multifamily - Deemed	2.1 ³⁵⁷	Custom	Actual Occupancy or Number of Bedrooms ³⁵⁸
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								
γ _{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 ³⁵⁹								
1.0	= Heat Capacity of water (1 Btu/lb*°F)								
3412	= Conversion from Btu to kWh								

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:

$$\begin{aligned}\Delta \text{kWh} &= [\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{FLHheat} * \\ &\quad \text{Capacity_heating} * (1/\text{HSPF}_{\text{base}} - 1/(\text{COP}_{\text{PL}} * 3.412))/1000] + [\text{ElecDHW} * \\ &\quad \% \text{DHWDisplaced} * ((1/\text{EF}_{\text{ELEC EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) \\ &\quad / 3412)] \\ \Delta \text{kWh} &= [730 * 36,000 * (1/14 - 1/19) / 1000] + [1754 * 36,000 * (1/8.2 - 1/(4.4 * 3.412)) / 1000] \\ &\quad + [1 * 0.44 * ((1/0.945 * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1)/3412)] \\ &= 494 + 3494 + 1328 \\ &= 5316 \text{ kWh}\end{aligned}$$

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:

$$\begin{aligned}\Delta \text{kWh for remaining life of existing unit (1st 8 years):} \\ &= [730 * 36,000 * (1/9.3 - 1/19) / 1000] + [1754 * 36,000 * (1/5.54 - 1/(4.4 * 3.412)) / 1000] \\ &\quad + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1)/3412)] \\ &= 1443 + 7191 + 1328 \\ &= 9,963 \text{ kWh} \\ \Delta \text{kWh for remaining measure life (next 17 years):} \\ &= (730 * 36,000 * (1/14 - 1/28) / 1000) + [1967 * 36,000 * (1/8.2 - 1/(4.4 * 3.412)) / 1000] \\ &\quad + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1)/3412)] \\ &= 494 + 3494 + 1328 \\ &= 5316 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

New Construction and Time of Sale:

$$\Delta \text{kW} = (\text{Capacity_cooling} * (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{FL}}))/1000 * \text{CF}$$

Early replacement:

$$\begin{aligned}\Delta \text{kW for remaining life of existing unit (1st 8 years):} \\ &= (\text{Capacity_cooling} * (1/\text{EER}_{\text{exist}} - 1/\text{EER}_{\text{FL}}))/1000 * \text{CF} \\ \Delta \text{kW for remaining measure life (next 17 years):} \\ &= (\text{Capacity_cooling} * (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{FL}}))/1000 * \text{CF}\end{aligned}$$

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

EER_{exist} = Energy Efficiency Ratio of existing cooling unit (kBtu/hr / kW)

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

$$\text{EER}_{\text{exist}} = (-0.02 * \text{SEER}_{\text{exist}}^2) + (1.12 * \text{SEER}_{\text{exist}}) \quad ^{363}$$

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 unit³⁶⁹

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

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:

$$\begin{aligned}\Delta kW_{SSP} &= (36,000 * (1/11.8 - 1/19))/1000 * 0.72 \\ &= 0.83 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} &= (36,000 * (1/11 - 1/19))/1000 * 0.466 \\ &= 0.54 \text{ kW}\end{aligned}$$

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:

$$\begin{aligned}\Delta kW_{SSP} \text{ for remaining life of existing unit (1st 8 years):} \\ &= (36,000 * (1/7.5 - 1/19))/1000 * 0.72 \\ &= 2.09 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{SSP} \text{ for remaining measure life (next 17 years):} \\ &= (36,000 * (1/11.8 - 1/19))/1000 * 0.72 \\ &= 0.83 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} \text{ for remaining life of existing unit (1st 8 years):} \\ &= (36,000 * (1/7.5 - 1/19))/1000 * 0.466 \\ &= 1.35 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} \text{ for remaining measure life (next 17 years):} \\ &= (36,000 * (1/11.8 - 1/19))/1000 * 0.466 \\ &= 0.54 \text{ kW}\end{aligned}$$

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:

$$\begin{aligned}\Delta \text{Therms} &= [\text{Heating Savings}] + [\text{DHW Savings}] \\ &= [\text{Replaced gas consumption} - \text{therm equivalent of GSHP source kWh}] + [\text{DHW Savings}] \\ &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUEbase}) - (\text{kWh to Therm} * \text{FLHheat} * \\ &\quad \text{Capacity_heating} * 1/(\text{COP}_{PL} * 3.412))/1000)] + [(1 - \text{ElecDHW}) * \% \text{DHWD} \text{Displaced} * (1/ \\ &\quad \text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma \text{Water} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) / 100,000)]\end{aligned}$$

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

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

$$\begin{aligned}\Delta \text{Therms} &= [\text{Heating Savings}] + [\text{DHW Savings}] \\ &= [\text{Replaced gas consumption} - \text{therm equivalent of base ASHP source kWh}] + [\text{DHW Savings}] \\ &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUEbase}) - (\text{kWh to Therm} * \text{FLHheat} * \\ &\quad \text{Capacity_heating} * 1/\text{HSPF}_{\text{ASHP}})/1000)] + [(1 - \text{ElecDHW}) * \% \text{DHWD} \text{Displaced} * (1/ \text{EF}_{\text{GAS}} \\ &\quad \text{EXIST} * \text{GPD} * \text{Household} * 365.25 * \gamma \text{Water} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) / 100,000)]\end{aligned}$$

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:

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

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

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

$$= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{exist}}) - (\text{kWh to Therm} * \text{FLHheat} * \text{Capacity_heating} * 1/(\text{COP}_{\text{PL}} * 3.412))/1000)] + [(1 - \text{ElecDHW}) * \% \text{DHW Displaced} * (1/ \text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) / 100,000]]$$

Δ Therms for remaining measure life (next 17 years):

$$= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{baseER}}) - (\text{kWh to Therm} * \text{FLHheat} * \text{Capacity_heating} * 1/(\text{COP}_{\text{PL}} * 3.412))/1000)] + [(1 - \text{ElecDHW}) * \% \text{DHW Displaced} * (1/ \text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) / 100,000]]$$

If measure is supported by electric utility only, Δ Therms = 0

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

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

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

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

$$= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{exist}}) - (\text{kWh to Therm} * \text{FLHheat} * \text{Capacity_heating} * 1/\text{HSPF}_{\text{ASHP}})/1000)] + [(1 - \text{ElecDHW}) * \% \text{DHW Displaced} * (1/ \text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) / 100,000]]$$

Δ Therms for remaining measure life (next 17 years):

$$= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{baseER}}) - (\text{kWh to Therm} * \text{FLHheat} * \text{Capacity_heating} * 1/\text{HSPF}_{\text{ASHP}})/1000)] + [(1 - \text{ElecDHW}) * \% \text{DHW Displaced} * (1/ \text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) / 100,000]]$$

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 equivalent³⁷³.

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 standard³⁷⁹:

For ≤ 55 gallons: $0.6483 - (0.0017 * \text{storage capacity in gallons})$

For > 55 gallons $0.7897 - (0.0004 * \text{storage capacity in gallons})$

= 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:

$\Delta kWh = 0$

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

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

= $[(1 - ElecHeat) * ((Gas_Heating_Load/AFUE_{base}) - (kWh_{toTherm} * FLH_{heat} * Capacity_{heating} * 1/(COP_{PL} * 3.412)/1000))] + [(1 - ElecDHW) * \%DHW_{Displaced} * (1/EF_{GAS\ EXIST} * GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 100,067]$

= $[(1-0) * ((714/0.80) - (10000/100000 * 1754 * 36,000 * 1/(4.4 * 3.412))/1000)] + [(1 - 0) * (0.44 * (1/0.58 * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1) / 100,067)]$

= 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]

= $[(FLH_{cool} * Capacity_{cooling} * (1/SEER_{exist} - (1/EER_{PL})/1000)] + [(FLH_{heat} * Capacity_{heating} * (1/HSPF_{ASHP} - (1/COP_{PL} * 3.412))/1000] + [ElecDHW * \%DHW_{Displaced} * (((1/EF_{ELEC}) * GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 3412)]$

= $[(730 * 36,000 * (1/8.6 - 1/19)) / 1000] + [(1754 * 36,000 * (1/8.2 - 1/(4.4 * 3.412)))/1000] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1)/3412)]$

= 1673 + 3494 + 0

= 5167 kWh

Continued on next page.

³⁷⁹ Minimum Federal Standard as of 4/1/2015.

Illustrative Example continued

Δ kWh for remaining measure life (next 17 years):

$$\begin{aligned}
 &= [\text{Cooling savings}] + [\text{Heating savings}] + [\text{DHW savings}] \\
 &= [(\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{base}} - (1/\text{EER}_{\text{PL}})/1000)] + [(\text{FLHheat} * \text{Capacity_heating} * (1/\text{HSPF}_{\text{ASHP}} - (1/\text{COP}_{\text{PL}} * 3.412))/1000] + [\text{ElecDHW} * \% \text{DHWD} \text{Displaced} * ((1/\text{EF}_{\text{ELEC}}) * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)] \\
 &= [(730 * 36,000 * (1/13 - 1/19)) / 1000] + [1754 * 36,000 * (1/8.2 - 1/(4.4 * 3.412)) / 1000] + [0 * 0.44 * ((1/0.904) * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1) / 3412)] \\
 &= 638 + 3494 + 0 \\
 &= 4132 \text{ kWh}
 \end{aligned}$$

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

$$\begin{aligned}
 &= [\text{Heating Savings}] + [\text{DHW Savings}] \\
 &= [\text{Replaced gas consumption} - \text{therm equivalent of base ASHP source kWh}] + [\text{DHW Savings}] \\
 &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{Exist}}) - (\text{kWh to Therm} * \text{FLHheat} * \text{Capacity_heating} * 1/\text{HSPF}_{\text{ASHP}})/1000)] + [(1 - \text{ElecDHW}) * \% \text{DHWD} \text{Displaced} * (1/\text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 100,000)] \\
 &= [(1-0) * ((714/0.644) - (10000/100000 * 1754 * 36,000 * 1/8.2)/1000)] + [(1 - 0) * (0.44 * (1/0.58 * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1) / 100,000)] \\
 &= 339 + 74 \\
 &= 412 \text{ therms}
 \end{aligned}$$

Δ Therms for remaining measure life (next 17 years):

$$\begin{aligned}
 &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{baseER}}) - (\text{kWh to Therm} * \text{FLHheat} * \text{Capacity_heating} * 1/\text{HSPF}_{\text{ASHP}})/1000)] + [(1 - \text{ElecDHW}) * \% \text{DHWD} \text{Displaced} * (1/\text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 100,000)] \\
 &= [(1-0) * ((714/0.9) - (10000/100000 * 1754 * 36,000 * 1/8.2)/1000)] + [(1 - 0) * (0.44 * (1/0.58 * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1) / 100,000)] \\
 &= 23 + 74 \\
 &= 97 \text{ therms}
 \end{aligned}$$

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 Δ kWh 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.

$$\begin{aligned}\Delta\text{Therms} &= [\text{Heating Consumption Replaced}^{380}] + [\text{DHW Savings if gas}] \\ &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUEbase})) + [(1 - \text{ElecDHW}) * \% \text{DHWDisplaced} \\ &\quad * (1/\text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma\text{Water} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 100,000]] \\ \Delta\text{kWh} &= - [\text{GSHP heating consumption}] + [\text{Cooling savings}^{381}] + [\text{DHW savings if electric}] \\ &= - [(\text{FLHheat} * \text{Capacity_heating} * (1/\text{COP}_{\text{PL}} * 3.412))/1000] + [(\text{FLHcool} * \\ &\quad \text{Capacity_cooling} * (1/\text{SEERbase} - 1/\text{EER}_{\text{PL}}))/1000] + [\text{ElecDHW} * \% \text{DHWDisplaced} * \\ &\quad ((1/\text{EF}_{\text{ELEC}} * \text{GPD} * \text{Household} * 365.25 * \gamma\text{Water} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)]\end{aligned}$$

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculate the annual savings for the remaining life (years 9-25)]:

$$\begin{aligned}\Delta\text{Therms} &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUEexist})) + [(1 - \text{ElecDHW}) * \\ &\quad \% \text{DHWDisplaced} * (1/\text{EF}_{\text{GAS EXIST}} * \text{GPD} * \text{Household} * 365.25 * \gamma\text{Water} * (T_{\text{OUT}} - \\ &\quad T_{\text{IN}}) * 1.0) / 100,067]] \\ &= [(1-0) * (714/0.644)] + [((1-0) * 0.44 * (1/0.58 * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) \\ &\quad * 1) / 100,0067)] \\ &= 1109 + 74 \\ &= 1183 \text{ therms} \\ \Delta\text{kWh} &= - [(\text{FLHheat} * \text{Capacity_heating} * (1/\text{COP}_{\text{PL}} * 3.412))/1000] + [(\text{FLHcool} * \\ &\quad \text{Capacity_cooling} * (1/\text{SEERexist} - 1/\text{EER}_{\text{PL}}))/1000] + [\text{ElecDHW} * \\ &\quad \% \text{DHWDisplaced} * (((1/\text{EF}_{\text{ELEC}}) * \text{GPD} * \text{Household} * 365.25 * \gamma\text{Water} * (T_{\text{OUT}} - T_{\text{IN}}) \\ &\quad * 1.0) / 3412)] \\ &= - [(1754 * 36,000 * (1/(4.4 * 3.412)))/ 1000] + [(730 * 36,000 * (1/9.3 - 1/19))/ 1000] + \\ &\quad [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1)/3412)] \\ &= -4206 + 1443 + 0 \\ &= -2763 \text{ kWh}\end{aligned}$$

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 sonas 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 sonas) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2 - 2016³⁸². 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 years³⁸³.

DEEMED MEASURE COST

Incremental cost per installed fan is \$43.50 for quiet, efficient fans³⁸⁴.

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**

$$\Delta \text{kWh} = (\text{CFM} * (1/\eta_{\text{BASELINE}} - 1/\eta_{\text{EFFICIENT}})/1000) * \text{Hours}$$

Where:

CFM	= Nominal Capacity of the exhaust fan
	= Actual or use defaults provided below
	= Assume 50CFM for continuous ventilation ³⁸⁵
η_{BASELINE}	= Average efficacy for baseline fan (CFM/watts)
	= See table below
$\eta_{\text{EFFICIENT}}$	= 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 below³⁸⁷:

Application	Min CFM	Max CFM	Average CFM	Base CFM/Watts	ENERGY STAR		ENERGY STAR Most Efficient	
					CFM/Watts	Δ kWh Savings	CFM/Watts	Δ kWh 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

$$\Delta \text{kW} = (\text{CFM} * (1/\eta_{\text{BASELINE}} - 1/\eta_{\text{EFFICIENT}})/1000) * \text{CF}$$

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 Δ kW Savings	ENERGY STAR Most Efficient Δ kW 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 years³⁸⁸.

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 \$175³⁸⁹.

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

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)'.

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

$$= 46.6\%^{392}$$

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh_{\text{Central AC}} = (\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{CAC}}))/1000 * \text{MFe}$$

$$\Delta kWh_{\text{Air Source Heat Pump}} = ((\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{ASHP}}))/1000 * \text{MFe}) + (\text{FLHheat} * \text{Capacity_heating} * (1/\text{HSPF}_{\text{ASHP}}))/1000 * \text{MFe}$$

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

= Actual

SEER_{CAC} = SEER Efficiency of existing central air conditioning unit receiving maintenance

= Actual. If unknown assume 10 SEER³⁹⁵

MFe = Maintenance energy savings factor

= 0.05³⁹⁶

SEER_{ASHP} = SEER Efficiency of existing air source heat pump unit receiving maintenance

= Actual. If unknown assume 10 SEER³⁹⁷

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)	FLH _{heat}
1 (Rockford)	2208
2 (Chicago)	2064
3 (Springfield)	1967
4 (Belleville)	1420
5 (Marion)	1445
Weighted Average ³⁹⁹	1821

Capacity_{heating} = Heating capacity 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 maintenance

= Actual. If unknown assume 6.8 HSPF⁴⁰⁰

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

$$\begin{aligned}\Delta \text{kWh}_{\text{CAC}} &= (730 * 36,000 * (1/10))/1000 * 0.05 \\ &= 131 \text{ kWh}\end{aligned}$$

For example, maintenance of a 3-ton, SEER 10, HSPF 6.8 air source heat pump unit in a single family house in Springfield:

$$\begin{aligned}\Delta \text{kWh}_{\text{ASHP}} &= ((730 * 36,000 * (1/10))/1000 * 0.05) + (1967 * 36,000 * (1/6.8))/1000 * 0.05 \\ &= 652 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \text{Capacity}_{\text{cooling}} * (1/\text{EER})/1000 * \text{MFd} * \text{CF}$$

Where:

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

= Calculate using Actual SEER

$$= -0.02 * \text{SEER}^2 + 1.12 * \text{SEER}^{401}$$

³⁹⁸ 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 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:

$$\begin{aligned}\Delta kW_{SSP} &= 36,000 * 1/(9.2)/1000 * 0.02 * 0.68 \\ &= 0.0532 \text{ kW} \\ \Delta kW_{PJM} &= 36,000 * 1/(9.2)/1000 * 0.02 * 0.466 \\ &= 0.0365 \text{ kW}\end{aligned}$$

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 assumption⁴⁰⁶. 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 years⁴⁰⁷. 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 \$30⁴⁰⁸. The cost for reprogramming is assumed to be \$10 to account for the auditor's time to reprogram and educate the homeowner.

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**

$$\Delta \text{kWh}^{409} = \% \text{ElectricHeat} * \text{Elec_Heating_Consumption} * \text{Heating_Reduction} * \text{HF} * \text{Eff_ISR} + (\Delta \text{Therms} * F_e * 29.3)$$

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 homes⁴¹¹. If location and heating type is unknown, assume 15,683 kWh⁴¹²

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

Δ Therms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

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

= 3.14%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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For example, a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield:

$$\begin{aligned}\Delta\text{kWh} &= 1 * 17,794 * 0.062 * 100\% * 100\% + (0 * 0.0314 * 29.3) \\ &= 1,103 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A due to no savings from cooling during the summer peak period.

NATURAL GAS ENERGY SAVINGS

$$\Delta\text{Therms} = \%FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR$$

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 below⁴²¹.

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:

$$\begin{aligned}\Delta\text{Therms} &= 1.0 * 1005 * 0.062 * 100\% * 100\% \\ &= 62.3 \text{ therms}\end{aligned}$$

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 than⁴²³:

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 11.8⁴²⁵ 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 years⁴²⁶.

For early replacement, the remaining life of existing equipment is assumed to be 6 years⁴²⁷.

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 ASHP⁴²⁸ or \$2,011 for a new baseline 80% AFUE furnace or \$3,543 for a new 82% AFUE boiler⁴²⁹ and \$952 per ton⁴³⁰ 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 applied⁴³¹:

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 below⁴³³.

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 replacement⁴³⁴. 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 territory⁴³⁶.

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):

$$\begin{aligned}\Delta kWh &= [\text{Heating Savings}] + [\text{Cooling Savings}] \\ &= [(\text{Elecheat} * \text{Capacity}_{\text{heat}} * \text{EFLH}_{\text{heat}} * (1/\text{HSPF}_{\text{Base}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} * \text{EFLH}_{\text{cool}} * (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]\end{aligned}$$

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

If measure is supported by gas utility only, $\Delta kWh = 0$

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

$$\begin{aligned}\Delta kWh &= [\text{Heating Savings from base ASHP to DMSHP}] + [\text{Cooling Savings}] \\ &= [(\text{Capacity}_{\text{heat}} * \text{EFLH}_{\text{heat}} * (1/\text{HSPF}_{\text{ASHP}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} * \text{EFLH}_{\text{cool}} * (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]\end{aligned}$$

Early replacement (non-fuel switch only)⁴⁴¹:

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

$$\begin{aligned}\Delta kWh &= [\text{Heating Savings}] + [\text{Cooling Savings}] \\ &= [(\text{Elecheat} * \text{Capacity}_{\text{heat}} * \text{EFLH}_{\text{heat}} * (1/\text{HSPF}_{\text{Exist}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} * \text{EFLH}_{\text{cool}} * (1/\text{SEER}_{\text{Exist}} - 1/\text{SEER}_{\text{ee}})) / 1000]\end{aligned}$$

ΔkWh for remaining measure life (next 12 years):

$$\begin{aligned}\Delta kWh &= [\text{Heating Savings}] + [\text{Cooling Savings}] \\ &= [(\text{Elecheat} * \text{Capacity}_{\text{heat}} * \text{EFLH}_{\text{heat}} * (1/\text{HSPF}_{\text{Base}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} * \text{EFLH}_{\text{cool}} * (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]\end{aligned}$$

Early replacement - fuel switch only :

If measure is supported by gas utility only, $\Delta kWh = 0$

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

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):

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

$$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Exist} - 1/SEER_{ee})) / 1000]$$

ΔkWh for remaining measure life (next 12 years):

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

$$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$$

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)
= 8.2⁴⁴⁶

$HSPF_{ee}$ = HSPF rating of new equipment (kbtu/kwh)
= Actual installed

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr⁴⁴⁷.
= Actual installed

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

Existing Cooling System	SEER _{base}
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 installed⁴⁵¹

$SEER_{exist}$ = 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 below⁴⁵⁵.

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:

$$\begin{aligned}\Delta \text{kWh}_{\text{heat}} &= (18000 * 1421 * (1/3.412 - 1/8))/1000 = 4,299 \text{ kWh} \\ \Delta \text{kWh}_{\text{cool}} &= (18000 * 308 * (1/8.0 - 1/14))/1000 = 297 \text{ kWh} \\ \Delta \text{kWh} &= 4,299 + 297 = 4,596 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

New Construction and Time of Sale:

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

Early replacement:

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

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

ΔkW for remaining measure life (next 12 years):

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

Where:

EER_{base} = 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:

$$\text{EER}_{\text{exist}} = (-0.02 * \text{SEER}_{\text{exist}}^2) + (1.12 * \text{SEER}_{\text{exist}}) \quad ^{460}$$

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.

$$EFLH_{\text{heat}} * 1/(HSPF_{\text{ee}})/1000)]$$

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

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

$$\begin{aligned}\Delta\text{Therms} &= [\text{Heating Savings}] \\ &= [\text{Replaced gas consumption} - \text{therm equivalent of base ASHP source kWh}] \\ &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{base}}) - (\text{kWh to Therm} * \text{Capacity}_{\text{heat}} * \\ &\quad EFLH_{\text{heat}} * 1/(HSPF_{\text{ASHP}})/1000)]\end{aligned}$$

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):

$$\begin{aligned}&= [\text{Heating Savings}] \\ &= [\text{Replaced gas consumption} - \text{therm equivalent of DMSHP source kWh}] \\ &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{exist}}) - (\text{kWh to Therm} * \text{Capacity}_{\text{heat}} * \\ &\quad EFLH_{\text{heat}} * 1/(HSPF_{\text{ee}})/1000)]\end{aligned}$$

ΔTherms for remaining measure life (next 12 years):

$$= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{baseER}}) - (\text{kWh to Therm} * \text{Capacity}_{\text{heat}} * EFLH_{\text{heat}} * 1/(HSPF_{\text{ee}})/1000)]$$

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

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

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

$$\begin{aligned}\Delta\text{Therms} &= [\text{Heating Savings}] \\ &= [\text{Replaced gas consumption} - \text{therm equivalent of base ASHP source kWh}] \\ &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{exist}}) - (\text{kWh to Therm} * \text{Capacity}_{\text{heat}} * \\ &\quad EFLH_{\text{heat}} * 1/(HSPF_{\text{ASHP}})/1000)]\end{aligned}$$

ΔTherms for remaining measure life (next 12 years):

$$= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{baseER}}) - (\text{kWh to Therm} * \text{Capacity}_{\text{heat}} * EFLH_{\text{heat}} * 1/(HSPF_{\text{ASHP}})/1000)]$$

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 equivalent⁴⁷⁰.

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.

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.

$$\begin{aligned}\Delta \text{Therms} &= [\text{Heating Consumption Replaced}]^{476} \\ &= [(1 - \text{ElecHeat}) * ((\text{Gas_Heating_Load}/\text{AFUE}_{\text{base}})] \\ \Delta kWh &= - [\text{DMSHP heating consumption}] + [\text{Cooling savings}]^{477} \\ &= - [(\text{Capacity}_{\text{heat}} * \text{EFLH}_{\text{heat}} * 1/\text{HSPFee})/1000] + [(\text{Capacity}_{\text{cool}} * \text{EFLH}_{\text{cool}} * (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]\end{aligned}$$

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 requirements⁴⁷⁸ 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 visit⁴⁷⁹:

- 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.

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

$$\Delta \text{kWh} = \Delta \text{Therms} * F_e * 29.3$$

Where:

ΔTherms = as calculated below

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
 = 3.14%⁴⁸¹

⁴⁸⁰Act 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.

$$\Delta Therms = \frac{ConsumptionPre - ConsumptionPost}{100,000}$$

$$\Delta Therms = \frac{\left((CAPInput_{pre} * EFLH) - \left(CAPInput_{post} * EFLH * \left(\frac{CAPOutput_{pre}}{CAPOutput_{post}} \right) \right) \right)}{100,000}$$

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

CAOutput_{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:

$$\Delta \text{Therms} = (\text{CAPInput}_{\text{pre}} * \text{EFLH} * (1/\text{Effbefore} - 1/(\text{Effbefore} + \text{Ei})))$$

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 years⁴⁸⁶

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 13 years⁴⁸⁷. See section below for detail.

DEEMED MEASURE COST

The cost of this measure is \$612⁴⁸⁸

LOADSHAPE

NA

COINCIDENCE FACTOR

N/A

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

$$\Delta \text{Therms} = \text{Gas_Boiler_Load} * (1/\text{AFUE}) * \text{Savings Factor}$$

Where:

Gas_Boiler_Load⁴⁸⁹

= Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below⁴⁹⁰.

= or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent⁴⁹¹.

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 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations should be completed by contractors during the selection process and may be readily available for program data purposes.

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

$$\begin{aligned}\Delta \text{Therms} &= 1275 * (1/0.925) * 0.05 \\ &= 69 \text{ Therms}\end{aligned}$$

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
η_{Heat}	Boiler	82% AFUE

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 13 years⁴⁹³.

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 year⁴⁹⁴ (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

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

$$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{light}$$

$$\Delta kWh_{fan} = [Days * FanHours * ((\%Low_{base} * WattsLow_{base}) + (\%Med_{base} * WattsMed_{base}) + (\%High_{base} * WattsHigh_{base}))/1000] - [Days * FanHours * ((\%Low_{ES} * WattsLow_{ES}) + (\%Med_{ES} * WattsMed_{ES}) + (\%High_{ES} * WattsHigh_{ES}))/1000]$$

$$\Delta kWh_{light} = \text{see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.}$$

Where⁴⁹⁷:

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
%Low _{ES}	= 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

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:

$$\begin{aligned}\Delta kWh_{fan} &= [365.25 * 3 * ((0.4 * 15) + (0.4 * 34) + (0.2 * 67)) / 1000] - \\ &\quad [365.25 * 3 * ((0.4 * 6) + (0.4 * 23) + (0.2 * 56)) / 1000] \\ &= 36.2 - 25.0 = 11.2 \text{ kWh} \\ \Delta kWh_{light} &= ((129 - 42) / 1000) * 759 * 1.06 \\ &= 70.0 \text{ kWh} \\ \Delta kWh &= 11.2 + 70 \\ &= 81.2 \text{ kWh}\end{aligned}$$

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kW_{Fan} + \Delta kW_{light}$$

$$\Delta kW_{Fan} = ((WattsHigh_{base} - WattsHigh_{ES}) / 1000) * CF_{fan}$$

$$\Delta kW_{Light} = \text{see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.}$$

Where:

$$\begin{aligned}CF_{fan} &= \text{Summer Peak coincidence factor for ventilation savings} \\ &= 30\%^{498}\end{aligned}$$

⁴⁹⁸ Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report

$$\begin{aligned} CF_{\text{light}} &= \text{Summer Peak coincidence factor for lighting savings} \\ &= 7.1\%^{499} \end{aligned}$$

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:

$$\begin{aligned} \Delta kW_{\text{fan}} &= ((67-56)/1000) * 0.3 \\ &= 0.0033 \text{ kW} \\ \Delta kW_{\text{light}} &= ((129 - 42)/1000) * 1.11 * 0.071 \\ &= 0.0068 \text{ kW} \\ \Delta kW &= 0.0033 + 0.0068 \\ &= 0.010 \text{ kW} \end{aligned}$$

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 communication⁵⁰² 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 assumed⁵⁰⁴.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for advanced thermostats is assumed to be 11 years⁵⁰⁵.

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) programs⁵⁰⁶, or other program types actual costs are still preferable⁵⁰⁷ but if unknown then the average incremental cost for the new installation measure is assumed to be \$125⁵⁰⁸.

LOADSHAPE

ΔkWh	→ 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

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 homes⁵¹³. If location and heating type is unknown, assume 15,683 kWh⁵¹⁴

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

Δ Therms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

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

= 3.14%⁵²¹

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: $8.8\% \times 0.43 + 5.6\% \times 0.57$. 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 ($96.5\% = 100\% \times 90\% + 65\% \times 10\%$) 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 unit⁵²⁷. (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 STAR version 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 homes⁵²⁸. If building type is unknown, assume 31,864Btu/hr⁵²⁹.

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 thermostat⁵³¹:
= 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:

$$\begin{aligned}
 \Delta \text{kWh} &= \Delta \text{kWh}_{\text{heating}} + \Delta \text{kWh}_{\text{cooling}} \\
 &= 1 * 10,464 * 5.6\% * 100\% * 100\% + (0 * 0.0314 * 29.3) + 100\% * ((730 * 33,600 * (1/9.3))/1000) * 6.3\% * 100\% \\
 &= 586\text{kWh} + 166 \text{ kWh} \\
 &= 752 \text{ kWh}
 \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \% \text{AC} * (\text{Cooling_Reduction} * \text{Btu/hr} * (1/\text{EER})/1000) * \text{EFF_ISR} * \text{CF}$$

Where:

EER = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)
= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:

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 calculate 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:

$$\Delta kW_{SSP} = 100\% * (6.3\% * 33,600 * (1/7.5)/1000) * 100\% * 34\% \\ = 0.096 \text{ kW}$$

$$\Delta kW_{PJM} = 100\% * (6.3\% * 33,600 * (1/7.5)/1000) * 100\% * 23.3\% \\ = 0.066 \text{ kW}$$

NATURAL GAS ENERGY SAVINGS

$$\Delta \text{Therms} = \% \text{FossilHeat} * \text{Gas_Heating_Consumption} * \text{Heating_Reduction} * \text{HF} * \text{Eff_ISR}$$

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 below⁵³⁸.

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:

$$\begin{aligned}\Delta\text{Therms} &= 1.0 * 1005 * 5.6\% * 100\% * 100\% \\ &= 56.28 \text{ therms}\end{aligned}$$

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 \$3,522⁵⁴¹

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

$$\Delta \text{Therms} = \Delta \text{Therm}_{\text{Boiler}} + \Delta \text{Therm}_{\text{WH}}$$

$$\Delta \text{Therms}_{\text{Boiler}} = (\text{EFLH} * \text{CAPInput} * (\text{AFUE}(\text{eff}) / \text{AFUE}(\text{base}) - 1)) / 100000$$

$$\Delta \text{Therms}_{\text{WH}} = (1/\text{UEF}_{\text{Base}} - 1/\text{UEF}_{\text{Eff}}) * (\text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 100,000$$

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%.⁵⁴⁴AFUE_{Base} = Baseline boiler annual fuel utilization efficiency rating

= 82%

AFUE_{Eff} = Efficient boiler annual fuel utilization efficiency rating= Actual. If unknown, use defaults dependent⁵⁴⁵ 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: $0.6483 - (0.0017 \times \text{storage capacity in gallons})$
 = For >55 gallons: $0.7897 - (0.0004 \times \text{storage capacity in gallons})$
 = 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.
 = 0.933⁵⁴⁶
- GPD** = Gallons per day of hot water use per person
 = 45.5 gallons hot water per day per household/2.59 people per household⁵⁴⁷
 = 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
- γ_{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°F⁵⁵¹

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. $2.75 \times 93\%$ 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%:

$$\Delta\text{Therms}_{\text{Boiler}} = (1022 * 80,000 * (0.95/0.82 - 1))/100000$$

$$\Delta\text{Therms}_{\text{SWH}} = (1/0.5803 - 1/0.933) * (17.6 * 2.56 * 365.25 * 8.33 * (125-54) * 1.0)/100,000$$

$$\Delta\text{Therms} = 129.6 + 63.4$$

$$= 193.0 \text{ Therms}$$

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 years⁵⁵².

DEEMED MEASURE COST

The measure cost including material and installation is assumed to be \$3 per linear foot⁵⁵³.

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).

	$= 1.0^{554}$
R _{new}	= 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) * $\pi/12$) = Actual (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)
C _{new}	= Circumference of pipe (ft) (Diameter (in) * $\pi/12$) = Actual (0.5" pipe and 3/8" foam ((0.5 + 3/8 + 3/8) * $\pi/12$) = .327 ft)
ΔT	= Average temperature difference between supplied water and outside air temperature (°F) = 60°F ⁵⁵⁵
8,766	= Hours per year
η_{DHW}	= 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:

$$\begin{aligned}
 \Delta kWh &= ((C_{\text{exist}} / R_{\text{exist}} - C_{\text{new}} / R_{\text{new}}) * L * \Delta T * 8,766) / \eta_{DHW} / 3412 \\
 &= ((0.196/1 - 0.327/5) * 5 * 60 * 8766) / 0.98 / 3412 \\
 &= 106 \text{ kWh}
 \end{aligned}$$

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.

$$\begin{aligned}
 \Delta kWh &= ((C_{\text{exist}} / R_{\text{exist}} - C_{\text{new}} / R_{\text{new}}) * L * \Delta T * 8,766) / \eta_{DHW} / 3412 \\
 &= ((0.196/1 - 0.327/5) * 3 * 60 * 8766) / 0.98 / 3412 \\
 &= 64 \text{ kWh per 3ft length}
 \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / 8766$$

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:

$$\begin{aligned}\Delta kW &= 106/8766 \\ &= 0.0121kW\end{aligned}$$

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.

$$\begin{aligned}\Delta kW &= 64/8766 \\ &= 0.0073 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

For Natural Gas DHW systems:

$$\Delta \text{Therm} = ((C_{\text{exist}} / R_{\text{exist}} - C_{\text{new}} / R_{\text{new}}) * L * \Delta T * 8,766) / \eta_{\text{DHW}} / 100,000$$

Where:

$$\begin{aligned}\eta_{\text{DHW}} &= \text{Recovery efficiency of gas hot water heater} \\ &= 0.78^{557}\end{aligned}$$

Other variables as defined above

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

$$\begin{aligned}\Delta \text{Therm} &= ((0.196/1 - 0.327/5) * 5 * 60 * 8766) / 0.78 / 100,000 \\ &= 4.40 \text{ therms}\end{aligned}$$

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.

$$\begin{aligned}\Delta \text{Therm} &= ((C_{\text{exist}} / R_{\text{exist}} - C_{\text{new}} / R_{\text{new}}) * L * \Delta T * 8,766) / \eta_{\text{DHW}} / 100,000 \\ &= ((0.196/1 - 0.327/5) * 3 * 60 * 8766) / 0.78 / 100,000 \\ &= 2.64 \text{ therms per 3ft length}\end{aligned}$$

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 $0.6483 - (0.0017 \times \text{storage capacity in gallons})$ and $0.7897 - (0.0004 \times \text{storage capacity in gallons})$ 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

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 years⁵⁶¹.

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 below⁵⁶².

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 \$650⁵⁶³. 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:

$$\Delta \text{Therms} = (1/\text{UEF}_{\text{BASE}} - 1/\text{UEF}_{\text{EFFICIENT}}) * (\text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 100,000$$

Early replacement⁵⁶⁴:

ΔTherms for remaining life of existing unit (1st 3.7 years for gas storage unit and 1st 6.7 years for gas tankless unit):

$$= (1/\text{UEF}_{\text{EXISTING}} - 1/\text{UEF}_{\text{EFFICIENT}}) * (\text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 100,000$$

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).

Δ Therms 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 standards⁵⁶⁵
- = For gas storage water heaters ≤55 gallons: $0.6483 - (0.0017 * \text{storage capacity in gallons})$
- = For gas storage water heaters >55 gallons: $0.7897 - (0.0004 * \text{storage capacity in gallons})$
- = 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 0.91⁵⁶⁶. 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 heaters⁵⁶⁷
- 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 0.52⁵⁶⁸
- GPD = Gallons Per Day of hot water use per person
- = 45.5 gallons hot water per day per household/2.59 people per household⁵⁶⁹
- = 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
γ_{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 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:

$$\Delta \text{Therms} = (1/0.58 - 1/0.80) * (17.6 * 2.56 * 365.25 * 8.33 * (125 - 54) * 1) / 100,000$$

$$= 46.15 \text{ therms}$$

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 heater⁵⁷⁴.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a new electric water heater meeting federal minimum efficiency standards⁵⁷⁵, dependent on the storage volume (in gallons) of the water heater.

For units ≤55 gallons – resistance storage unit with efficiency: $0.9307 - (0.0002 * \text{rated volume in gallons})$

For units >55 gallons – assume a 50 gallon resistance tank baseline⁵⁷⁶ 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 boilers⁵⁷⁸. 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 below⁵⁷⁹. 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 FACTORThe summer Peak Coincidence Factor is assumed to be 12%.⁵⁸⁰**Algorithm****CALCULATION OF SAVINGS****ELECTRIC ENERGY SAVINGS**

$$\Delta \text{kWh} = (((1/\text{UEF}_{\text{BASE}} - 1/\text{UEF}_{\text{EFFICIENT}}) * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412) + \text{kWh}_{\text{cooling}} - \text{kWh}_{\text{heating}}$$

Where:

UEF_{BASE} = Uniform Energy Factor (efficiency) of standard electric water heater according to federal standards⁵⁸¹:

For ≤55 gallons: $0.96 - (0.0003 * \text{rated volume in gallons})$

For >55 gallons: $2.057 - (0.00113 * \text{rated volume in gallons})$

= If unknown volume, use 0.945 for a 50 gallon tank, the most common size for HPWH

$\text{UEF}_{\text{EFFICIENT}}$ = 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 household⁵⁸²

= 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

γ_{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°F⁵⁸⁶

1.0 = Heat Capacity of water (1 Btu/lb*°F)

3412 = Conversion from Btu to kWh

$\text{kWh}_{\text{cooling}}^{\text{587}}$ = Cooling savings from conversion of heat in home to water heat

$= (((((\text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412) -$

$((1 / \text{UEF}_{\text{NEW}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)) *$
 $\text{LF} * 27\%) / \text{COP}_{\text{COOL}} * \text{LM}$

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 savings⁵⁸⁸

COP_{COOL} = COP of central air conditioning

= Actual, if unknown, assume 2.8⁵⁸⁹

LM = Latent multiplier to account for latent cooling demand

= 1.33⁵⁹⁰

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

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 $(-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$ (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to $\text{COP} = \text{EER} / 3.412 = 2.8 \text{COP}$.

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.

$$= (((((GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 3412) - ((1 / UEF_{NEW} * GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 49\%) / COP_{HEAT}) * (1 - \%NaturalGas)$$

Where:

49% = Portion of reduced waste heat that results in increased heating load⁵⁹¹

COP_{HEAT} = COP of electric heating system

= actual. If not available use⁵⁹²:

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:

$$\Delta kWh = [(1 / 0.945 - 1 / 2.0) * 17.6 * 2.56 * 365.25 * 8.33 * (125 - 54)] / 3412 + 188.9 - 0$$

$$= 1781 kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

Hours = Full load hours of water heater

= 2533⁵⁹⁴

CF = Summer Peak Coincidence Factor for measure

= 0.12⁵⁹⁵

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:

$$\begin{aligned} \text{kW} &= 1838 / 2533 * 0.12 \\ &= 0.087\text{kW} \end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta\text{Therms} = -(((\text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412) - (((\text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412) / \text{UEF}_{\text{EFFICIENT}})) * \text{LF} * 49\% * 0.03412) / \eta_{\text{Heat}} * \% \text{NaturalGas}$$

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)

η_{Heat} = Efficiency of heating system
= Actual.⁵⁹⁷ If not available use 70%.⁵⁹⁸

$\% \text{NaturalGas}$ = Factor dependent on heating fuel:

Heating System	$\% \text{NaturalGas}$
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):

$$\begin{aligned} \Delta\text{Therms} &= -(((17.6 * 2.56 * 365.25 * 8.33 * (125 - 54) * 1.0) / 3412) - (17.6 * 2.56 * 365.25 * 8.33 * (125 - 54) * 1.0 / 3412 / 2.0)) * 1 * 0.49 * 0.03412) / (0.7 * 1) \\ &= - 34.1 \text{ therms} \end{aligned}$$

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
η_{Cool}	Central AC	13 SEER
	Heat Pump	14 SEER
η_{Heat}	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 boilers⁶⁰⁰.

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 \$3⁶⁰² 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 \$8⁶⁰³ 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

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).

$$\Delta \text{kWh} = \% \text{ElectricDHW} * ((\text{GPM}_{\text{base}} * \text{L}_{\text{base}} - \text{GPM}_{\text{low}} * \text{L}_{\text{low}}) * \text{Household} * 365.25 * \text{DF} / \text{FPH}) * \text{EPG}_{\text{electric}} * \text{ISR}$$

Where:

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

DHW fuel	$\% \text{ElectricDHW}$
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 studies⁶⁰⁷, or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor⁶⁰⁸

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 studies⁶¹¹ or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor⁶¹²

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

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 $(0.7*0.75)+(0.3*0.9)=0.795$.

⁶²⁸Based 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 = $(8.33 * 1.0 * (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE_electric} * 3412)$ = $(8.33 * 1.0 * (86 - 54.1)) / (0.98 * 3412)$ = 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:

$$\Delta \text{kWh} = 1.0 * (((1.63 * 4.5 - 0.94 * 4.5) * 2.56 * 365.25 * 0.75) / 1) * 0.0969 * 0.95$$

$$= 200 \text{ kWh}$$

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

$$\Delta \text{kWh} = 1.0 * (((1.53 * 1.6 - 0.94 * 1.6) * 2.1 * 365.25 * 0.90) / 1.5) * 0.0795 * 0.95$$

$$= 33.0 \text{ kWh}$$

For example, a direct installed low flow faucet aerator in unknown faucet in an individual electric DHW home:

$$\Delta \text{kWh} = 1.0 * (((1.58 * 9.0 - 0.94 * 9.0) * 2.56 * 365.25 * 0.795) / 3.83) * 0.0919 * 0.95$$

$$= 97.6 \text{ kWh}$$

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.

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

Where

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

$$= 5010^{641}$$

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

$$\begin{aligned}\Delta \text{Water (gallons)} &= (((1.63 * 4.5 - 0.94 * 4.5) * 2.56 * 365.25 * 0.75) / 1) * 0.95 \\ &= 2068 \text{ gallons} \\ \Delta \text{kWh}_{\text{water}} &= 2068 / 1000000 * 5010 \\ &= 10.4 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} * \text{CF}$$

Where:

ΔkWh = calculated value above.

Hours = Annual electric DHW recovery hours for faucet use per faucet

$$= ((\text{GPM}_{\text{base}} * \text{L}_{\text{base}}) * \text{Household} / \text{FPH} * 365.25 * \text{DF}) * 0.545^{642} / \text{GPH}$$

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:

$$\begin{aligned}\Delta \text{kW} &= 200 / 110 * 0.022 \\ &= 0.04 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \% \text{FossilDHW} * ((\text{GPM}_{\text{base}} * \text{L}_{\text{base}} - \text{GPM}_{\text{low}} * \text{L}_{\text{low}}) * \text{Household} * 365.25 * \text{DF} / \text{FPH}) * \text{EPG}_{\text{gas}} * \text{ISR}$$

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

$$= (8.33 * 1.0 * (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE_gas} * 100,000)$$

$$= 0.00341 \text{ Therm/gal for SF homes (Bath), } 0.00415 \text{ Therm/gal for SF homes (Kitchen), } 0.00394 \text{ Therm/gal for SF homes (Unknown)}$$

$$= 0.00397 \text{ Therm/gal for MF homes (Bath), } 0.00484 \text{ Therm/gal for MF homes (Kitchen), } 0.00459 \text{ Therm/gal for MF homes (Unknown)}$$

RE_gas = Recovery efficiency of gas water heater

$$= 78\% \text{ For individual water heater}^{645}$$

$$= 67\% \text{ For shared water heater}^{646}$$

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:

$$\Delta\text{Therms} = 1.0 * (((1.63 * 4.5 - 0.94 * 4.5) * 2.56 * 365.25 * 0.75) / 1) * 0.00415 * 0.95$$

$$= 8.58 \text{ Therms}$$

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

$$\Delta\text{Therms} = 1.0 * (((1.53 * 1.6 - 0.94 * 1.6) * 2.1 * 365.25 * 0.90) / 1.5) * 0.003974 * 0.95$$

$$= 1.64 \text{ Therms}$$

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

$$\Delta\text{Therms} = 1.0 * (((1.58 * 9.0 - 0.94 * 9.0) * 2.56 * 365.25 * 0.795) / 3.83) * 0.00394 * 0.95$$

$$= 4.18 \text{ Therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta\text{Water (gallons)} = ((\text{GPM_base} * \text{L_base} - \text{GPM_low} * \text{L_low}) * \text{Household} * 365.25 * \text{DF} / \text{FPH}) * \text{ISR}$$

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

$$\Delta \text{Water (gallons)} = (((1.63 * 4.5 - 0.94 * 4.5) * 2.56 * 365.25 * 0.75) / 1) * 0.95$$

$$= 2068 \text{ gallons}$$

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

$$\Delta \text{Water (gallons)} = (((1.53 * 1.6 - 0.94 * 1.6) * 2.1 * 365.25 * 0.90) / 1.5) * 0.95$$

$$= 413 \text{ gallons}$$

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

$$\Delta \text{Water (gallons)} = (((1.58 * 9.0 - 0.94 * 9.0) * 2.56 * 365.25 * 0.795) / 3.83) * 0.95$$

$$= 1062 \text{ gallons}$$

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 \$7⁶⁴⁸ 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 \$12⁶⁴⁹ 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

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

$$\Delta \text{kWh} = \% \text{ElectricDHW} * ((\text{GPM}_{\text{base}} * \text{L}_{\text{base}} - \text{GPM}_{\text{low}} * \text{L}_{\text{low}}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * \text{EPG}_{\text{electric}} * \text{ISR}$$

Where:

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

DHW fuel	$\% \text{ElectricDHW}$
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 evaluations 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.

$$= 7.8 \text{ min}^{655}$$

L_{low} = Shower length in minutes with low-flow showerhead
 $= 7.8 \text{ min}^{656}$

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
 $= (8.33 * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{electric}} * 3412)$
 $= (8.33 * 1.0 * (101 - 54.1)) / (0.98 * 3412)$

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
	= 101°F ⁶⁶⁶
SupplyTemp	= Assumed temperature of water entering house
	= 54.1°F 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:

$$\begin{aligned}\Delta\text{kWh} &= 1.0 * ((2.24 * 7.8 - 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.117 * 0.98 \\ &= 207 \text{ kWh}\end{aligned}$$

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.

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

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

$$E_{\text{water total}} = \text{IL Total Water Energy Factor (kWh/Million Gallons)} \\ = 5010^{674}$$

For example, a direct installed 1.5 GPM low flow showerhead in a single family where the number of showers is not known:

$$\begin{aligned} \Delta \text{Water (gallons)} &= ((2.24 * 7.8 - 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98 \\ &= 1773 \text{ gallons} \\ \Delta \text{kWh}_{\text{water}} &= 1773 / 1,000,000 * 5010 \\ &= 8.9 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta \text{kWh} / \text{Hours} * CF$$

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for showerhead use

$$= ((\text{GPM}_{\text{base}} * L_{\text{base}}) * \text{Household} * \text{SPCD} * 365.25) * 0.712^{675} / \text{GPH}$$

= 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

= 0.0278⁶⁷⁶

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:

$$\begin{aligned} \Delta kW &= 207 / 255 * 0.0278 \\ &= .022 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \% \text{FossilDHW} * ((\text{GPM}_{\text{base}} * L_{\text{base}} - \text{GPM}_{\text{low}} * L_{\text{low}}) * \text{Household} * \text{SPCD})$$

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 $7.23 / 260 = 0.0278$

$$* 365.25 / \text{SPH}) * \text{EPG}_{\text{gas}} * \text{ISR}$$

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
 $= (8.33 * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{gas}} * 100,000)$
 = 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 heater⁶⁷⁸
 = 67% For shared water heater⁶⁷⁹
 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:

$$\begin{aligned} \Delta \text{Therms} &= 1.0 * ((2.24 * 7.8 - 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98 \\ &= 8.9 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta \text{Water (gallons)} = ((\text{GPM}_{\text{base}} * \text{L}_{\text{base}} - \text{GPM}_{\text{low}} * \text{L}_{\text{low}}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * \text{ISR}$$

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:

$$\Delta \text{Water (gallons)} = ((2.24 * 7.8 - 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98$$

$$= 1773 \text{ gallons}$$

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:

$$\Delta kWh^{680} = (U * A * (T_{pre} - T_{post}) * \text{Hours} * \text{ISR}) / (3412 * RE_{\text{electric}})$$

Where:

U = Overall heat transfer coefficient of tank (Btu/Hr-°F-ft²).

= 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; $A = 24.99\text{ft}^2$

Capacity (gal)	A (ft ²) ⁶⁸¹
30	19.16
40	23.18
50	24.99
80	31.84

T_{pre} = Actual hot water setpoint prior to adjustment

T_{post} = Actual new hot water setpoint, which may not be lower than 120 degrees

Default Hot Water Temperature Inputs	
T _{pre}	135
T _{post}	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
= 0.98⁶⁸²

A deemed savings assumption, where site specific assumptions are not available would be as follows:

$$\begin{aligned}\Delta\text{kWh} &= (U * A * (T_{\text{pre}} - T_{\text{post}}) * \text{Hours} * \text{ISR}) / (3412 * \text{RE}_{\text{electric}}) \\ &= (((0.083 * 24.99) * (135 - 120) * 8766 * 1.0) / (3412 * 0.98)) \\ &= 81.6 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = \Delta\text{kWh} / \text{Hours} * \text{CF}$$

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%.

$$\Delta kW = (81.6 / 8766) * 1$$

$$\Delta kW \text{ default} = 0.00931 \text{ kW}$$

NATURAL GAS SAVINGS

For homes with gas water heaters:

$$\Delta \text{Therms} = (U * A * (T_{\text{pre}} - T_{\text{post}}) * \text{Hours} * \text{ISR}) / (100,000 * \text{RE}_{\text{gas}})$$

Where

$$100,000 = \text{Converts Btus to Therms (btu/Therm)}$$

$$\text{RE}_{\text{gas}} = \text{Recovery efficiency of gas water heater}$$

$$= 78\% \text{ For SF homes }^{683}$$

$$= 67\% \text{ For MF homes }^{684}$$

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:

$$\begin{aligned} \Delta \text{Therms} &= (U * A * (T_{\text{pre}} - T_{\text{post}}) * \text{Hours} * \text{ISR}) / (\text{RE}_{\text{gas}}) \\ &= (((0.083 * 24.99) * (135 - 120) * 8766 * 1.0) / (100,000 * 0.78)) \\ &= 3.5 \text{ Therms} \end{aligned}$$

For Multi Family homes:

$$\begin{aligned} \Delta \text{Therms} &= (U * A * (T_{\text{pre}} - T_{\text{post}}) * \text{Hours} * \text{ISR}) / (\text{RE}_{\text{gas}}) \\ &= (((0.083 * 24.99) * (135 - 120) * 8766 * 1.0) / (100,000 * 0.67)) \\ &= 4.1 \text{ Therms} \end{aligned}$$

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 years⁶⁸⁶.

DEEMED MEASURE COST

The incremental cost for this measure will be the actual material cost of procuring and labor cost of installing the tank wrap.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

This measure assumes a flat loadshape and as such the coincidence factor is 1.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For electric DHW systems:

$$\Delta \text{kWh} = ((A_{\text{base}} / R_{\text{base}} - A_{\text{insul}} / R_{\text{insul}}) * \Delta T * \text{Hours}) / (3412 * \eta_{\text{DHW}})$$

Where:

R_{base} = Overall thermal resistance coefficient prior to adding tank wrap (Hr-°F-ft²/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 ($Hr \cdot ^\circ F \cdot ft^2 / BTU$).
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 ($^\circ F$) = $60^\circ F$ ⁶⁸⁹
Hours	= Number of hours in a year (since savings are assumed to be constant over year). = 8766
3412	= Conversion from Btu to kWh
η_{DHW}	= 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)	R_{base}	R_{insul}	$A_{base} (ft^2)$ ⁶⁹¹	$A_{insul} (ft^2)$ 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 $125^\circ F$ water leaving the hot water tank and average temperature of basement of $65^\circ F$.

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 \$30⁶⁹⁴ plus \$20 labor⁶⁹⁵ 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

$$\Delta \text{kWh} = \% \text{ElectricDHW} * ((\text{GPM_base_S} * \text{L_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) *$$

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 $0.577 / 260 = 0.0022$

$$\text{EPG}_{\text{electric}} * \text{ISR}$$

Where:

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

DHW fuel	$\% \text{ElectricDHW}$
Electric	100%
Natural Gas	0%
Unknown	16% ⁶⁹⁷

$\text{GPM}_{\text{base_S}}$ = 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

$L_{\text{showerdevice}}$ = Hot water waste time avoided due to thermostatic restrictor valve

= 0.89 minutes⁷⁰⁰

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

$$= (8.33 * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{electric}} * 3412)$$

$$= (8.33 * 1.0 * (101 - 54.1)) / (0.98 * 3412)$$

$$= 0.117 \text{ kWh/gal}$$

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water

$$= 101\text{F}^{710}$$

SupplyTemp = Assumed temperature of water entering house

$$= 54.1\text{F}^{711}$$

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:

$$\begin{aligned}\Delta\text{kWh} &= 1.0 * (2.67 * 0.89 * 2.56 * 0.6 * 365.25 / 1.79) * 0.117 * 0.98 \\ &= 85 \text{ kWh}\end{aligned}$$

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.

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

Where

$$\begin{aligned}E_{\text{water total}} &= \text{IL Total Water Energy Factor (kWh/Million Gallons)} \\ &= 5,010^{715}\end{aligned}$$

For example, a direct installed thermostatic restrictor device in a home with an single family home where the number of showers is not known:

$$\begin{aligned}\Delta\text{Water (gallons)} &= ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98 \\ &= 730 \text{ gallons} \\ \Delta\text{kWh}_{\text{water}} &= 730 / 1,000,000 * 5010 \\ &= 3.7 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = \Delta\text{kWh/Hours} * \text{CF}$$

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

$$= ((\text{GPM}_{\text{base}_S} * L_{\text{showerdevice}}) * \text{Household} * \text{SPCD} * 365.25) * 0.712^{716} / \text{GPH}$$

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

$$= 27.51$$

$$= 34.4 \text{ for SF Direct Install; } 28.3 \text{ for MF Direct Install}$$

$$= 30.3 \text{ for SF Retrofit and TOS; } 24.8 \text{ for MF Retrofit and TOS}$$

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
= 0.0022⁷¹⁷

Example

For example, a direct installed thermostatic restrictor device in a home with electric DHW where the number of showers is not known.

$$\Delta kW = 85.3/34.4 * 0.0022$$

$$= 0.0055 \text{ kW}$$

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \% \text{FossilDHW} * ((\text{GPM_base_S} * \text{L_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * \text{EPG_gas} * \text{ISR}$$

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
= $(8.33 * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE_gas} * 100,000)$
= 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 homes⁷¹⁹
= 67% For MF homes⁷²⁰

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:

$$\Delta \text{Therms} = 1.0 * ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98$$

$$= 3.7 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta \text{Water (gallons)} = ((\text{GPM_base_S} * \text{L_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * \text{ISR}$$

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:

$$\Delta \text{Water (gallons)} = ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98$$

$$= 730 \text{ gallons}$$

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 years⁷²¹.

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

$$\Delta \text{kWh} = \% \text{Electric DHW} * \text{GPM} * (\text{L}_{\text{base}} - \text{L}_{\text{timer}}) * \text{Household} * \text{Days/yr} * \text{SPCD} * \text{UsageFactor} * \text{EPG}_{\text{Electric}}$$

Where:

$\% \text{Electric DHW}$ = 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 1.93⁷²⁴
- L_base = Number of minutes in shower without a shower timer
= 7.8 minutes⁷²⁵
- L_timer = Number of minutes in shower after shower timer
= Custom, to be determined through evaluation. If data is not available use 5.79⁷²⁶
- 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
= 0.6⁷³²
- UsageFactor = How often each participant is using shower timer
= Custom, to be determined through evaluation. If data is not available use 0.34⁷³³

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.

$$\begin{aligned}
 \text{EPG_Electric} &= \text{Energy per gallon of hot water supplied by electric} \\
 &= (8.33 * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE_electric} * 3412) \\
 &= (8.33 * 1.0 * (101 - 54.1)) / (0.98 * 3412) \\
 &= 0.117 \text{ kWh/gal}
 \end{aligned}$$

Based on default assumptions provided above, the savings for a single family home would be:

$$\begin{aligned}
 \Delta \text{kWh} &= \% \text{Electric DHW} * \text{GPM} * (\text{L_base} - \text{L_timer}) * \text{Household} * \text{Days/yr} * \text{SPCD} * \text{UsageFactor} \\
 &\quad * \text{EPG_Electric} \\
 &= 0.16 * 1.93 * (7.8 - 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.117 \\
 &= 13.9 \text{ kWh}
 \end{aligned}$$

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.

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

Where

$$\begin{aligned}
 E_{\text{water total}} &= \text{IL Total Water Energy Factor (kWh/Million Gallons)} \\
 &= 5,010^{734}
 \end{aligned}$$

Based on default assumptions provided above, the savings for a single family home would be:

$$\begin{aligned}
 \Delta \text{Water (gallons)} &= \text{GPM} * (\text{L_base} - \text{L_timer}) * \text{Household} * \text{Days/yr} * \text{SPCD} * \text{UsageFactor} \\
 &= 1.93 * (7.8 - 5.79) * 2.56 * 365.25 * 0.6 * 0.34 \\
 &= 740.0 \text{ gallons} \\
 \Delta \text{kWh}_{\text{water}} &= 740 / 1,000,000 * 5010 \\
 &= 3.7 \text{ kWh}
 \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \Delta \text{kWh/Hours} * \text{CF}$$

Where:

$$\begin{aligned}
 \Delta \text{kWh} &= \text{calculated value above. Note do not include the secondary savings in this calculation.} \\
 \text{Hours} &= \text{Annual electric DHW recovery hours for showerhead use} \\
 &= ((\text{GPM_base} * \text{L_base}) * \text{Household Users} * \text{SPCD} * 365.25) * 0.712 / \text{GPH} \\
 \text{GPH} &= \text{Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98\% recovery efficiency, and typical 4.5kW electric resistance storage tank.} \\
 &= 27.51 \\
 \text{CF} &= \text{Coincidence Factor for electric load reduction} \\
 &= 0.0278^{735}
 \end{aligned}$$

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:

$$\begin{aligned}\Delta kW &= \Delta kWh/Hours * CF \\ &= 0.0013 kW\end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \%FossilDHW * GPM * (L_{base} - L_{timer}) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas$$

$$\%FossilDHW = \text{Proportion of water heating supplied by electric resistance heating}$$

DHW fuel	%FossilDHW
Electric	0%
Natural Gas	100%
Unknown	84% ⁷³⁶

$$\begin{aligned}EPG_gas &= \text{Energy per gallon of Hot water supplied by gas} \\ &= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000) \\ &= 0.00501 \text{ Therm/gal for SF homes} \\ &= 0.00583 \text{ Therm/gal for MF homes}\end{aligned}$$

$$\begin{aligned}RE_gas &= \text{Recovery efficiency of gas water heater} \\ &= 78\% \text{ For SF homes }^{737} \\ &= 67\% \text{ For MF homes }^{738}\end{aligned}$$

Use Multifamily if: Building has shared DHW.

$$100,000 = \text{Converts Btus to Therms (btu/Therm)}$$

Other variables as defined above.

Based on default assumptions provided above, the savings for a single family home would be:

$$\begin{aligned}\Delta \text{ Therms} &= \%FossilDHW * GPM * (L_{base} - L_{timer}) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas \\ &= 0.84 * 1.93 * (7.8 - 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.00501 \\ &= 3.1 \text{ Therms}\end{aligned}$$

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

$$\Delta \text{Water (gallons)} = \text{GPM} * (\text{L_base} - \text{L_timer}) * \text{Household} * \text{Days/yr} * \text{SPCD} * \text{UsageFactor}$$

Variables as defined above

Based on default assumptions provided above, the savings for a single family home would be:

$$\begin{aligned} \Delta \text{Water (gallons)} &= \text{GPM} * (\text{L_base} - \text{L_timer}) * \text{Household} * \text{Days/yr} * \text{SPCD} * \text{UsageFactor} \\ &= 1.93 * (7.8 - 5.79) * 2.56 * 365.25 * 0.6 * 0.34 \\ &= 740.0 \text{ gallons} \end{aligned}$$

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 used⁷³⁹.

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 year⁷⁴⁰.

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 \$1.20⁷⁴¹.

For the Direct Install measure, the full cost of \$2.45 per bulb should be used, plus \$5 labor cost⁷⁴² 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 unknown⁷⁴³ and 7.4% for Residential Direct Install⁷⁴⁴.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta \text{kWh} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{WHFe}$$

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 appropriate⁷⁵²) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation or use deemed assumptions below⁷⁵³:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

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):

$$\begin{aligned}\Delta\text{kWh}_{1\text{st year installs}} &= ((43 - 14) / 1000) * 0.765 * 847 * 1.06 \\ &= 19.9 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\Delta\text{kWh}_{2\text{nd year installs}} &= ((43 - 14) / 1000) * 0.116 * 847 * 1.06 \\ &= 3.0 \text{ kWh}\end{aligned}$$

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

$$\begin{aligned}\Delta\text{kWh}_{3\text{rd year installs}} &= ((43 - 14) / 1000) * 0.099 * 847 * 1.06 \\ &= 2.6 \text{ kWh}\end{aligned}$$

HEATING PENALTY

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

$$\Delta\text{kWh}^{759} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF}) / \eta\text{Heat}$$

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 use⁷⁶¹:

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:

$$\begin{aligned}\Delta\text{kWh}_{1\text{st year}} &= - (((43 - 14) / 1000) * 0.765 * 759 * 0.49) / 2.0 \\ &= - 4.2 \text{ kWh}\end{aligned}$$

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

$$\Delta kW = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{WHFd} * \text{CF}$$

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:

$$\begin{aligned}\Delta kW &= ((43 - 14) / 1000) * 0.765 * 1.11 * 0.071 \\ &= 0.0017 \text{ kW}\end{aligned}$$

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):

$$\Delta \text{Therms}^{766} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF} * 0.03412) / \eta_{\text{Heat}}$$

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
 η_{Heat} = Efficiency of heating system
 =70%⁷⁶⁸

For example, a 14 standard CFL is purchased and installed in a home:

$$\Delta \text{Therms} = - ((43 - 14) / 1000) * 0.765 * 759 * 0.49 * 0.03412 / 0.7$$

$$= - 0.40 \text{ Therms}$$

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The O&M assumptions that should be used in cost effectiveness calculations are provided below:

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 used⁷⁷¹.

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 year⁷⁷² 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 year⁷⁷³.

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 \$5⁷⁷⁴.

For the Direct Install measure, the full cost of \$8.50 should be used plus \$5 labor⁷⁷⁵ 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 below⁷⁷⁶

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**

$$\Delta \text{kWh} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{WHFe}$$

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 wattage⁷⁷⁹; use 60W if unknown⁷⁸⁰

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 20W and 50 Lm/W for lamps with rated wattages >= 20 watts⁷⁸¹.

For Directional R, BR, and ER lamp types⁷⁸²:

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
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

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 unknown⁷⁸⁵

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 appropriate⁷⁹³) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below⁷⁹⁴:

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

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	W _{HFe}
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).

$$\begin{aligned}\Delta \text{kWh}_{1\text{st year installs}} &= ((60 - 13) / 1000) * 0.823 * 850 * 1.06 \\ &= 34.9 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\Delta \text{kWh}_{2\text{nd year installs}} &= ((43 - 13) / 1000) * 0.085 * 850 * 1.06 \\ &= 2.3 \text{ kWh}\end{aligned}$$

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

$$\begin{aligned}\Delta \text{kWh}_{3\text{rd year installs}} &= ((43 - 13) / 1000) * 0.072 * 850 * 1.06 \\ &= 1.9 \text{ kWh}\end{aligned}$$

Note: delta watts is equivalent to install year. Here we assume no change in hours assumption.

HEATING PENALTY

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

$$\Delta \text{kWh}^{798} = -(((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF}) / \eta_{\text{Heat}}$$

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 $(-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$ (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

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

η_{Heat} = Efficiency in COP of Heating equipment

= actual. If not available use⁸⁰⁰:

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):

$$\Delta \text{kWh}_{1\text{st year}} = - ((60 - 15) / 1000) * 0.823 * 639 * 0.49 / 2.0$$

$$= - 5.8 \text{ kWh}$$

Second and third year savings should be calculated using the appropriate ISR.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{WHFd} * \text{CF}$$

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 below⁸⁰⁴

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:

$$\begin{aligned}\Delta kW_{1st\ year} &= ((60 - 15) / 1000) * 0.823 * 1.11 * 0.081 \\ &= 0.003\ kW\end{aligned}$$

Second and third year savings should be calculated using the appropriate ISR.

NATURAL GAS SAVINGS

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

$$\Delta Therms^{807} = - (((WattsBase - WattsEE) / 1000) * ISR * (1 - Leakage) * Hours * HF * 0.03412) / \eta Heat$$

Where:

$$\begin{aligned}HF &= \text{Heating Factor or percentage of light savings that must be heated} \\ &= 49\%^{808} \text{ for interior or unknown location} \\ &= 0\% \text{ for exterior location} \\ 0.03412 &= \text{Converts kWh to Therms} \\ \eta Heat &= \text{Efficiency of heating system} \\ &= 70\%^{809}\end{aligned}$$

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:

$$\begin{aligned}\Delta\text{Therms} &= - ((60 - 15) / 1000) * 0.823 * 639 * 0.49 * 0.03412 / 0.7 \\ &= - 0.57 \text{ Therms}\end{aligned}$$

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 year⁸¹⁰; baseline replacement cost is assumed to be \$3.5⁸¹¹.

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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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 years⁸¹².

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be \$5⁸¹³.

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 locations⁸¹⁴.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = ((\Delta \text{Watts}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{HOURS} * \text{WHFe}$$

Where:

ΔWatts = Average delta watts per purchased ENERGY STAR torchiere

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 appropriate⁸¹⁷) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below⁸¹⁸:

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:

$$\Delta kWh = (115.8 / 1000) * 0.86 * 1095 * 1.06$$

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)

$$= 116 \text{ kWh}$$

For multi family in unit:

$$\begin{aligned}\Delta \text{kWh} &= (115.8 / 1000) * 0.86 * 1095 * 1.04 \\ &= 113 \text{ kWh}\end{aligned}$$

HEATING PENALTY

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

$$\Delta \text{kWh}^{822} = - ((\Delta \text{Watts}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{HOURS} * \text{HF} / \eta_{\text{Heat}}$$

Where:

HF = Heating Factor or percentage of light savings that must be heated
 = 49%⁸²³ for interior or unknown location

η_{Heat} = Efficiency in COP of Heating equipment
 = Actual. If not available use defaults provided below⁸²⁴:

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:

$$\begin{aligned}\Delta \text{kWh} &= - ((115.8) / 1000) * 0.86 * 1095 * 0.49 / 2.04 \\ &= - 26.2 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = ((\Delta \text{Watts}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{WHFd} * \text{CF}$$

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:

$$\Delta kW = (115.8 / 1000) * 0.86 * 1.11 * 0.071$$

$$= 0.008kW$$

For unknown location:

$$\Delta kW = (115.8 / 1000) * 0.86 * 1.07 * 0.081$$

$$= 0.009 kW$$

NATURAL GAS SAVINGS

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

$$\Delta \text{Therms}_{\text{SWH}} = - (((\Delta \text{Watts}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{HOURS} * 0.03412 * \text{HF}) / \eta_{\text{Heat}}$$

Where:

$\Delta \text{Therms}_{\text{SWH}}$ = 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

η_{Heat} = average heating system efficiency
= 70%⁸³⁰

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:

$$\begin{aligned}\Delta\text{Therms}_{\text{WH}} &= - ((115.8 / 1000) * 0.86 * 1095 * 0.03412 * 0.49) / 0.70 \\ &= - 2.60 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Life of the baseline bulb is assumed to be 1.83 years⁸³¹ 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 years⁸³³. 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 years⁸³⁴.

DEEMED MEASURE COST

The incremental cost for an exterior fixture is assumed to be \$32⁸³⁵.

LOADSHAPE

Loadshape R07 - Residential Outdoor Lighting

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**

$$\Delta \text{kWh} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours}$$

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 appropriate⁸⁴⁰) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below⁸⁴¹:

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).

$$\begin{aligned}\Delta\text{kWh}_{1\text{st year installs}} &= ((86 - 28) / 1000) * 0.875 * 2475 \\ &= 125.6 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\Delta\text{kWh}_{2\text{nd year installs}} &= ((86 - 28) / 1000) * 0.057 * 2475 \\ &= 8.2 \text{ kWh}\end{aligned}$$

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

$$\begin{aligned}\Delta\text{kWh}_{3\text{rd year installs}} &= ((86 - 28) / 1000) * 0.048 * 2475 \\ &= 6.9 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{CF}$$

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:

$$\begin{aligned}\Delta kW_{1st \text{ year}} &= ((86 - 28) / 1000) * 0.875 * 0.273 \\ &= 0.0142 \text{ kW}\end{aligned}$$

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 years⁸⁴⁴ 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 are actually in service and so should be multiplied by the appropriate ISR.

MEASURE CODE: RS-LRG-EFOX-V08-190101

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 years⁸⁴⁶. 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 year⁸⁴⁷.

DEEMED MEASURE COST

The incremental cost for an interior fixture is assumed to be \$32⁸⁴⁸.

LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

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**

$$\Delta \text{kWh} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{WHFe}$$

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% 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 appropriate⁸⁵³) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below⁸⁵⁴:

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.

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):

$$\Delta \text{kWh}_{1\text{st year installs}} = ((86 - 28) / 1000) * 0.875 * 759 * 1.06$$

$$= 40.8 \text{ kWh}$$

$$\Delta \text{kWh}_{2\text{nd year installs}} = ((86 - 28) / 1000) * 0.057 * 759 * 1.06$$

$$= 2.7 \text{ kWh}$$

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

$$\Delta \text{kWh}_{3\text{rd year installs}} = ((86 - 28) / 1000) * 0.048 * 759 * 1.06$$

$$= 2.2 \text{ kWh}$$

HEATING PENALTY

If electric heated building:

$$\Delta \text{kWh}^{858} = -(((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF}) / \eta_{\text{Heat}}$$

Where:

- HF = Heating Factor or percentage of light savings that must be heated
 = 49%⁸⁵⁹ for interior or unknown location
 = 0% for unheated location
- η_{Heat} = Efficiency in COP of Heating equipment
 = actual. If not available use⁸⁶⁰:

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:

$$\begin{aligned}\Delta kWh_{1st\ year} &= - (((86 - 28) / 1000) * 0.875 * 759 * 0.49) / 2.0 \\ &= - 9.4\ kWh\end{aligned}$$

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((WattsBase - WattsEE) / 1\ 000) * ISR * (1 - Leakage) * WHFd * CF$$

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:

$$\begin{aligned}\Delta kW_{1st\ year} &= ((86 - 28) / 1000) * 0.875 * 1.11 * 0.071 \\ &= 0.004\ kW\end{aligned}$$

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

NATURAL GAS SAVINGS

$$\Delta Therms^{865} = - (((WattsBase - WattsEE) / 1000) * ISR * (1 - Leakage) * Hours * HF * 0.03412) / \eta_{Heat}$$

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:

$$\Delta \text{Therms}_{1\text{st year}} = -((86 - 28) / 1000) * 0.875 * 759 * 0.49 * 0.03412) / 0.7$$

$$= - 0.9 \text{ Therms}$$

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Life of the baseline bulb is assumed to be 1.3 years⁸⁶⁸ 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 are 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 used⁸⁷⁰.

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 years⁸⁷¹ for exterior applications. For all other applications, lifetimes are capped at 10 years⁸⁷².

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 Dunskey 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 hours⁸⁷³.

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 following⁸⁷⁴:

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 bulbs⁸⁷⁵, 0.273 for exterior bulbs⁸⁷⁶ and 0.117 for unknown⁸⁷⁷. Use Multifamily if: Building meets utility's definition for multifamily.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * ISR * (1 - Leakage) * Hours * WHFe$$

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 (Watts _{EE})	Baseline From 1/1/2024 (Watts _{Base}) ⁸⁷⁹	Delta Watts From 1/1/2024 (Watts _{EE})
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 types⁸⁸⁰:

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 (Watt _{SEE})	Baseline 2014-2023 (Watts _{Base})	Delta Watts 2014-2023 (Watts _{EE})	Baseline From 1/1/2024 (Watts _{Base}) ⁸⁸¹	Delta Watts From 1/1/2024 (Watts _{EE})
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

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)

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 (Watt _{EE})	Baseline 2014-2023 (Watt _{Base})	Delta Watts 2014-2023 (Watt _{EE})	Baseline From 1/1/2024 (Watt _{Base}) ⁸⁸⁴	Delta Watts From 1/1/2024 (Watt _{EE})
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 1 st year In Service Rate (ISR)	2 nd year Installations	3 rd 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 1 st year In Service Rate (ISR)	2 nd year Installations	3 rd 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 appropriate⁸⁸⁹) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below⁸⁹⁰:

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:

$$\Delta \text{kWh} = ((45 - 13) / 1000) * 0.840 * (1 - 0.02) * 763 * 1.06$$

$$= 21.3 \text{ kWh}$$

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 (WattsEE)	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 (Watts _{EE})	Delta Watts 2014-2023 (Watts _{EE})	Delta Watts From 1/1/2024 (Watts _{EE})	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 (Watts _{EE})	Delta Watts From 1/1/2024 (Watts _{EE})	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):

$$\Delta \text{kWh}^{898} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF}) / \eta \text{Heat}$$

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:

$$\Delta \text{kWh} = -(((45 - 13) / 1000) * 0.840 * (1 - 0.02) * 763 * 0.49) / 2.04$$

$$= - 4.83 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{WHFd} * \text{CF}$$

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 bulbs⁹⁰⁶, 0.273 for exterior bulbs⁹⁰⁷ 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.

unknown⁹⁰⁸.

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:

$$\begin{aligned}\Delta kW &= (((45 - 13) / 1000) * 0.840 * (1 - 0.02) * 1.11 * 0.109 \\ &= 0.0032 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

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

$$\Delta \text{therms} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF} * 0.03412) / \eta \text{Heat}$$

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.

= 0.70⁹¹¹

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:

$$\begin{aligned}\Delta \text{therms} &= - (((45 - 13) / 1000) * 0.840 * (1 - 0.02) * 763 * 0.49 * 0.03412) / 0.70 \\ &= - 0.49 \text{ therms}\end{aligned}$$

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 below⁹¹².

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 below⁹¹⁷.

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 are 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 years⁹¹⁸.

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 1 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.
= 1.04⁹²⁴

Default if replacing incandescent fixture

$$\Delta \text{kWh} = (35 - 2) / 1000 * 8766 * 1.04$$

$$= 301 \text{ kWh}$$

Default if replacing dual sided fluorescent fixture

$$\Delta \text{kWh} = (14 - 4) / 1000 * 8766 * 1.04$$

$$= 91 \text{ kWh}$$

Default if replacing single sided fluorescent (or unknown) fixture

$$\Delta \text{kWh} = (7 - 2) / 1000 * 8766 * 1.04$$

$$= 46 \text{ kWh}$$

HEATING PENALTY

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

$$\Delta \text{kWh}^{925} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{Hours} * \text{HF}) / \eta_{\text{Heat}}$$

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 49%⁹²⁶

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 $(-0.02 * \text{SEER2}) + (1.12 * \text{SEER})$ (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to $\text{COP} = \text{EER} / 3.412 = 2.8\text{COP}$) 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.

η_{Heat} = 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:

$$\begin{aligned} \text{If incandescent fixture: } \Delta \text{kWh} &= -((35 - 2)/1000 * 8766 * 0.49) / 2 \\ &= -71 \text{ kWh} \end{aligned}$$

$$\begin{aligned} \text{If unknown fixture } \Delta \text{kWh} &= -((7 - 2)/1000 * 8766 * 0.49) / 2 \\ &= -10.7 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{WHF}_d * \text{CF}$$

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.
 =1.07⁹²⁹

CF = Summer Peak Coincidence Factor for measure
 = 1.0

Default if incandescent fixture

$$\begin{aligned} \Delta \text{kW} &= (35 - 2)/1000 * 1.07 * 1.0 \\ &= 0.035 \text{ kW} \end{aligned}$$

Default if dual sided fluorescent fixture

$$\begin{aligned} \Delta \text{kW} &= (14 - 4)/1000 * 1.07 * 1.0 \\ &= 0.0107 \text{ kW} \end{aligned}$$

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

$$\begin{aligned}\Delta kW &= (7 - 2) / 1000 * 1.07 * 1.0 \\ &= 0.0054 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

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

$$\Delta \text{Therms} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{Hours} * \text{HF} * 0.03412) / \eta \text{Heat}$$

Where:

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

$$= 49\%^{930}$$

0.03412 = Converts kWh to Therms

η Heat = Average heating system efficiency.

$$= 0.70^{931}$$

Other factors as defined above

Default if incandescent fixture

$$\begin{aligned}\Delta \text{Therms} &= - (((35 - 2) / 1000) * 8766 * 0.49 * 0.03412) / 0.70 \\ &= -6.9 \text{ therms}\end{aligned}$$

Default if dual sided fluorescent fixture

$$\begin{aligned}\Delta \text{Therms} &= - (((14 - 4) / 1000) * 8766 * 0.49 * 0.03412) / 0.70 \\ &= -2.1 \text{ therms}\end{aligned}$$

Default if single sided fluorescent fixture

$$\begin{aligned}\Delta \text{Therms} &= - (((7 - 2) / 1000) * 8766 * 0.49 * 0.03412) / 0.70 \\ &= -1.05 \text{ therms}\end{aligned}$$

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.

Component	Baseline Measures	
	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

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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 used⁹³⁴.

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 years⁹³⁵ for exterior application. For all other applications, lifetimes are capped at 10 years⁹³⁶.

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 hours⁹³⁷.

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 following⁹³⁸:

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 Dunskey 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 bulbs⁹³⁹, 0.273 for exterior bulbs⁹⁴⁰ and 0.135 for unknown⁹⁴¹.

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 1 st year In Service Rate (ISR)	2 nd year Installations	3 rd 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 appropriate⁹⁵²) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below⁹⁵³:

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.

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 as 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:

$$\Delta \text{kWh} = ((29.0 - 6.7) / 1000) * 0.784 * (1 - 0.007) * 1,089 * 1.06$$

$$= 20.0 \text{ kWh}$$

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.

$$\Delta \text{kWh}_{2\text{nd year installs}} = ((29 - 6.7) / 1000) * 0.106 * (1 - 0.007) * 1,089 * 1.06$$

$$= 2.7 \text{ kWh}$$

$$\Delta \text{kWh}_{3\text{rd year installs}} = ((29 - 6.7) / 1000) * 0.09 * (1 - 0.007) * 1,089 * 1.06$$

$$= 2.3 \text{ kWh}$$

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):

$$\Delta \text{kWh}^{960} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF}) / \eta_{\text{Heat}}$$

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
- η_{Heat} = Efficiency in COP of Heating equipment
- = actual. If not available use⁹⁶³:

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:

$$\Delta \text{kWh}_{1\text{st year}} = - ((29 - 6.7) / 1000) * 0.784 * (1 - 0.007) * 1,089 * 0.42 / 2.0$$

$$= - 4.0 \text{ kWh}$$

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{WHFd} * \text{CF}$$

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:

$$\begin{aligned}\Delta kW &= ((29 - 6.7) / 1000) * 0.784 * (1 - 0.007) * 1.11 * 0.128 \\ &= 0.0025 \text{ kW}\end{aligned}$$

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.

$$\Delta \text{Therms} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF} * 0.03412) / \eta_{\text{Heat}}$$

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
 η_{Heat} = Average heating system efficiency.
 = 0.70⁹⁷³

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Bulb replacement costs assumed in the O&M calculations are provided below⁹⁷⁴.

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 below⁹⁷⁸. 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:

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

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:

$$(0.24 \times 0.92) + (0.76 \times 0.8) \times (1 - 0.15) = 0.70$$

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 Bulbs⁹⁸⁰.

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 fixtures⁹⁸¹. 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 years⁹⁸² 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:

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 Dunskey 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 fixtures⁹⁸⁵, 0.273 for exterior fixtures⁹⁸⁶ and 0.127 for unknown⁹⁸⁷.

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 below⁹⁸⁹

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 appropriate⁹⁹¹) of the Utility Jurisdiction.

Upstream (TOS) Lighting programs = Use deemed assumptions below⁹⁹²:

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 Dunskey 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:

$$\begin{aligned}\Delta \text{kWh} &= ((88.5 - 22.4) / 1000) * 1.0 * (1 - 0.007) * 926 * 1.06 \\ &= 64.4 \text{ kWh}\end{aligned}$$

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 $(64.4 * 0.47) = 30.3 \text{ kWh}$ 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):

$$\Delta \text{kWh}^{1001} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF}) / \eta \text{Heat}$$

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 :

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:

$$\Delta \text{kWh}_{1\text{st year}} = - ((88.5 - 22.4) / 1000) * 1.0 * (1 - 0.007) * 926 * 0.49 / 2.0$$

$$= - 14.9 \text{ kWh}$$

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{WHFd} * \text{CF}$$

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:

$$\begin{aligned}\Delta kW &= ((88.5 - 22.4) / 1000) * 1.0 * (1-0.007) * 1.11 * 0.119 \\ &= 0.0087 \text{ kW}\end{aligned}$$

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.

$$\Delta \text{Therms} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF} * 0.03412) / \eta \text{Heat}$$

Where:

$$\begin{aligned}\text{HF} &= \text{Heating factor, or percentage of lighting savings that must be replaced by heating system.} \\ &= 49\%^{1012} \text{ for interior or unknown location} \\ &= 0\% \text{ for exterior location} \\ &= 42\%^{1013} \text{ for unknown location} \\ 0.03412 &= \text{Converts kWh to Therms} \\ \eta \text{Heat} &= \text{Average heating system efficiency.} \\ &= 0.70^{1014}\end{aligned}$$

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 below¹⁰¹⁵.

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 below¹⁰¹⁹. 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:

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 Assumptions¹⁰²⁵

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	<p>= Adjustment to account for the percentage of program string lights that move out (and in, if deemed appropriate) of the Utility Jurisdiction.</p> <p>= 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:</p> <table> <tr> <td>ComEd:</td><td>0.7%</td></tr> <tr> <td>Ameren:</td><td>13.1%</td></tr> </table>	ComEd:	0.7%	Ameren:	13.1%
ComEd:	0.7%				
Ameren:	13.1%				
Hours	<p>= Average hours of use per year</p> <p>= 210 hours¹⁰²⁷</p>				
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:

$$\begin{aligned}\Delta \text{kWh} &= ((0.49 * 50) - (0.11 * 50)) / 1000 * 1.00 * (1 - 0) * 210 * 1.0 \\ &= 4.0 \text{ kWh}\end{aligned}$$

HEATING PENALTY

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

$$\Delta \text{kWh}^{1028} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF}) / \eta_{\text{Heat}}$$

Where:

HF	<p>= Heating Factor or percentage of light savings that must be heated</p> <p>= 49% for interior or unknown location¹⁰²⁹</p> <p>= 0% for exterior or unheated location</p>
η_{Heat}	<p>= Efficiency in COP of Heating equipment</p> <p>= actual. If not available, use:¹⁰³⁰</p>

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):

$$\Delta \text{kWh} = - (((0.49 * 50) - (0.11 * 50)) / 1000) * 1.00 * (1 - 0) * 210 * 0.49 / 2.0$$

$$= - 1.0 \text{ kWh}$$

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.

$$\Delta \text{Therms} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{HF} * 0.03412) / \eta \text{Heat}$$

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:

$$\begin{aligned}\Delta\text{therms} &= - (((0.49 * 50) - (0.11 * 50)) / 1000) * 1.00 * (1 - 0) * 210 * 0.49 * 0.03412 / 0.70 \\ &= - 0.10 \text{ therms}\end{aligned}$$

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 years¹⁰³⁴.

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 following¹⁰³⁵:

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

$$\Delta \text{kWh} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{Hours} * \text{WHFe}$$

Where:

$$\text{Watts}_{\text{base}} = \text{Actual wattage if known, if unknown, assume } 7\text{W}^{1036}.$$

¹⁰³⁴ Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCREL0029 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.

Watt_{SEE} = Actual wattage of LED purchased / installed.

ISR = In Service Rate or the percentage of nightlights rebated that get installed

Program	Weighted Average 1 st year In Service Rate (ISR)	2 nd year Installations	3 rd 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 appropriate¹⁰⁴¹) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below¹⁰⁴²:

ComEd: 2.0%

Ameren: 13.1%

Hours = Average hours of use per year

= 4,380¹⁰⁴³

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 $(-0.02 * SEER^2) + (1.12 * SEER)$ (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), 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:

$$\begin{aligned}\Delta\text{kWh} &= ((7 - 0.3) / 1000) * 0.969 * (1 - 0) * 4380 * 1.06 \\ &= 30.1 \text{ kWh}\end{aligned}$$

HEATING PENALTY

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

$$\Delta\text{kWh}^{1047} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{Hours} * \text{HF}) / \eta\text{Heat}$$

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:

$$\begin{aligned}\Delta kWh &= - (((7 - 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49) / 2.04 \\ &= - 6.83 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * (1 - \text{Leakage}) * \text{WHFd} * \text{CF}$$

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.

$$\Delta \text{therms} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{Hours} * \text{HF} * 0.03412) / \eta \text{Heat}$$

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

η Heat = Average heating system efficiency.

= 0.70¹⁰⁵⁵

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:

$$\begin{aligned}\Delta \text{therms} &= - (((7 - 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49 * 0.03412) / 0.70 \\ &= - 0.68 \text{ therms}\end{aligned}$$

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 boilers¹⁰⁵⁷. 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.

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

Where:

- $\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to air sealing
 = $\frac{(((CFM50_{existing} - CFM50_{new})/N_{cool}) * 60 * 24 * CDD * DUA * 0.018)}{(1000 * \eta_{Cool}) * LM * ADJ_{AirSealingCool}}$
- $CFM50_{existing}$ = 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 location¹⁰⁶²:

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).

= 0.75¹⁰⁶³

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

1000 = Converts Btu to kBtu

η_{Cool} = 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 following¹⁰⁶⁴:

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 demand¹⁰⁶⁵

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, CLEARResult "Infiltration Factor Calculations Methodology.doc".

$ADJ_{AirSealingCool}$ = Adjustment for cooling savings to account for inaccuracies in engineering algorithms¹⁰⁶⁶

Measure	$ADJ_{AirSealingCool}$
Air sealing and attic insulation	121%
Air sealing without attic insulation	100%

$\Delta kWh_{heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \left(\frac{((CFM50_{existing} - CFM50_{new}) / N_{heat}) * 60 * 24 * HDD * 0.018}{(\eta_{Heat} * 3,412)} \right)$$

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

η_{Heat} = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate)..
If not available refer to default table below¹⁰⁶⁹:

¹⁰⁶⁶ As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). *ComEd 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	$\eta_{\text{Heat COP Estimate}} = (\text{HSPF}/3.413) * 0.85$
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:

$$\begin{aligned}
 \Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}} \\
 &= [(((3,400 - 2,250) / 31.6) * 60 * 24 * 842 * 0.75 * 0.018) / (1000 * 10.5) * 3.2 * 121\%] + \\
 &\quad [(((3,400 - 2,250) / 19.4) * 60 * 24 * 5113 * 0.018) / (1.92 * 3,412)] \\
 &= 220 + 1,199 \\
 &= 1,419 \text{ kWh}
 \end{aligned}$$

$\Delta \text{kWh}_{\text{heating}}$ = If gas furnace heat, kWh savings for reduction in fan run time

$$= \Delta \text{Therms} * F_e * 29.3 * \text{ADJ}_{\text{AirSealingHeatFan}}$$

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
 $= 3.14\%$ ¹⁰⁷⁰

29.3 = kWh per therm

$\text{ADJ}_{\text{AirSealingHeatFan}}$ = Adjustment for fan savings during heating season to account for inaccuracies in engineering algorithms¹⁰⁷¹

Measure	$\text{ADJ}_{\text{AirSealingHeatFan}}$
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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

¹⁰⁷¹ As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). *ComEd 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):

$$\begin{aligned}\Delta\text{kWh} &= 76.3 * 0.0314 * 29.3 * 107\% \\ &= 75.1 \text{ kWh}\end{aligned}$$

Methodology 2: Prescriptive Infiltration Reduction Measures¹⁰⁷²

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

$$\Delta\text{kWh}_{\text{heating}} = (\Delta\text{kWh}_{\text{gasket}} * n_{\text{gasket}} + \Delta\text{kWh}_{\text{sweep}} * n_{\text{sweep}} + \Delta\text{kWh}_{\text{sealing}} * l_{\text{sealing}} + \Delta\text{kWh}_{\text{WX}} * l_{\text{WX}}) * \text{ADJ}_{\text{RxAirsealing}}$$

Where:

$\Delta\text{kWh}_{\text{gasket}}$ = Annual kWh savings from installation of air sealing gasket on an electric outlet

Climate Zone (City based upon)	$\Delta\text{kWh}_{\text{gasket}} / \text{gasket}$	
	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

$\Delta\text{kWh}_{\text{sweep}}$ = Annual kWh savings from installation of door sweep

Climate Zone (City based upon)	$\Delta\text{kWh}_{\text{sweep}} / \text{sweep}$	
	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

$\Delta\text{kWh}_{\text{sealing}}$ = Annual kWh savings from foot of caulking, sealing, or polyethylene tape

Climate Zone (City based upon)	$\Delta\text{kWh}_{\text{sealing}} / \text{ft}$	
	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)	$\Delta kWh_{\text{sealing}} / \text{ft}$	
	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

l_{sealing} = linear feet of caulking, sealing, or polyethylene tape

ΔkWh_{wx} = Annual kWh savings from window weatherstripping or door weatherstripping

Climate Zone (City based upon)	$\Delta kWh_{\text{wx}} / \text{ft}$	
	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

l_{wx} = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{\text{RxAirsealing}}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings¹⁰⁷³.

= 80%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = $(\Delta kWh_{\text{cooling}} / \text{FLH}_{\text{cooling}}) * CF$

Where:

$\text{FLH}_{\text{cooling}}$ = Full load hours of air conditioning

= Dependent on location¹⁰⁷⁴:

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.

$$= 68\%^{1075}$$

$$CF_{SSP} = \text{Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)}$$

$$= 72\%^{1076}$$

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

$$= 46.6\%^{1077}$$

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:

$$\Delta kW_{SSP} = 220 / 570 * 0.68$$

$$= 0.26 \text{ kW}$$

$$\Delta kW_{PJM} = 220 / 570 * 0.466$$

$$= 0.18 \text{ kW}$$

NATURAL GAS SAVINGS

Methodology 1: Blower Door Test

Preferred methodology unless blower door testing is not possible.

If Natural Gas heating:

$$\Delta \text{Therms} = (((CFM50_{\text{existing}} - CFM50_{\text{new}}) / N_{\text{heat}}) * 60 * 24 * HDD * 0.018) / (\eta_{\text{Heat}} * 100,000) * ADJ_{\text{AirSealingGasHeat}}$$

Where:

$$N_{\text{heat}} = \text{Conversion factor from leakage at 50 Pascal to leakage at natural conditions}$$

$$= \text{Based on climate zone and building height}^{1078}$$

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 location¹⁰⁷⁹:

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

η_{Heat} = Efficiency of heating system
 = Equipment efficiency * distribution efficiency
 = Actual¹⁰⁸⁰ (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency¹⁰⁸¹.

$ADJ_{\text{AirSealingGasHeat}}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms¹⁰⁸²

Measure	$ADJ_{\text{AirSealingGasHeat}}$
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:

$$\Delta \text{Therms} = ((3,400 - 2,250) / 19.4) * 60 * 24 * 5113 * 0.018 / (0.72 * 100,000) * 72\%$$

$$= 78.5 \text{ therms}$$

Methodology 2: Prescriptive Infiltration Reduction Measures¹⁰⁸³

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). *ComEd 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.

$$\Delta\text{therms} = (\Delta\text{therms}_{\text{gasket}} * n_{\text{gasket}} + \Delta\text{therms}_{\text{sweep}} * n_{\text{sweep}} + \Delta\text{therms}_{\text{sealing}} * l_{\text{sealing}} + \Delta\text{therms}_{\text{SWX}} * l_{\text{WX}}) * \text{ADJ}_{\text{RxAirsealing}}$$

Where:

$\Delta\text{therms}_{\text{gasket}}$ = Annual therm savings from installation of air sealing gasket on an electric outlet

Climate Zone (City based upon)	$\Delta\text{therms}_{\text{gasket}} / \text{gasket}$ 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

$\Delta\text{therms}_{\text{sweep}}$ = Annual therm savings from installation of door sweep

Climate Zone (City based upon)	$\Delta\text{therms}_{\text{sweep}} / \text{sweep}$ 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

$\Delta\text{therms}_{\text{sealing}}$ = Annual therm savings from foot of caulking, sealing, or polyethylene tape

Climate Zone (City based upon)	$\Delta\text{therms}_{\text{sealing}} / \text{ft}$ Gas Heat
1 (Rockford)	0.54
2 (Chicago)	0.52
3 (Springfield)	0.45
4 (Belleville)	0.36
5 (Marion)	0.37

l_{sealing} = linear feet of caulking, sealing, or polyethylene tape

$\Delta\text{therms}_{\text{SWX}}$ = Annual therm savings from window weatherstripping or door weatherstripping

Climate Zone (City based upon)	$\Delta\text{therms}_{\text{SWX}} / \text{ft}$ Gas Heat
1 (Rockford)	0.63
2 (Chicago)	0.61
3 (Springfield)	0.53
4 (Belleville)	0.42
5 (Marion)	0.43

l_{WX} = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings¹⁰⁸⁴.
= 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
η_{Cool}	Central AC	13 SEER
	Heat Pump	14 SEER
η_{Heat}	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 boilers¹⁰⁸⁵.

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 boilers¹⁰⁸⁷. 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.

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.

$$\Delta kWh = (\Delta kWh_{cooling} + \Delta kWh_{heating})$$

Where:

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to insulation

$$= (((1/R_{old_AG} - 1/(R_{added} + R_{old_AG})) * L_{basement_wall_total} * H_{basement_wall_AG} * (1 - Framing_factor)) * 24 * CDD * DUA) / (1000 * \eta_{Cool})) * ADJ_{BasementCool}$$

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 1.0¹⁰⁹¹

$L_{basement_wall_total}$ = 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 insulation¹⁰⁹²

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:¹⁰⁹³

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

η_{Cool} = 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	η_{Cool} 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 savings¹⁰⁹⁸.
= 80%

$\Delta kWh_{heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= (((1/R_{old_AG} - 1/(R_{added} + R_{old_AG})) * L_{basement_wall_total} * H_{basement_wall_AG} * (1 - Framing_factor)) + ((1/R_{old_BG} - 1/(R_{added} + R_{old_BG})) * L_{basement_wall_total} * (H_{basement_wall_total} - H_{basement_wall_AG}) * (1 - Framing_factor))) * 24 * HDD / (3,412 * \eta_{Heat})) * ADJ_{BasementHeat}$$

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 ($H_{\text{basement_wall_total}} - H_{\text{basement_wall_AG}}$):

= 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-ft ² -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

$H_{\text{basement_wall_total}}$ = 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

η_{Heat} = 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	η_{Heat} (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	η_{Heat} (Effective COP Estimate) (HSPF/3.413)*0.85
Resistance	N/A	N/A	1

$ADJ_{\text{BasementHeat}}$ = Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings¹¹⁰³.
= 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:

$$\begin{aligned}\Delta k\text{Wh} &= (\Delta k\text{Wh}_{\text{cooling}} + \Delta k\text{Wh}_{\text{heating}}) \\ &= [((((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1 - 0)) * 24 * 281 * 0.75)/(1000 * 10.5)) * 0.8] + [((((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0)) + ((1 / (2.25 + 6.42) - 1 / (13 + 2.25 + 6.42)) * (20+25+20+25) * 4 * (1-0))) * 24 * 3079) / (3412 * 1.92)) * 0.6] \\ &= (39.4 + 860.9) \\ &= 900.3 \text{ kWh}\end{aligned}$$

$\Delta k\text{Wh}_{\text{heating}}$ = If gas furnace heat, kWh savings for reduction in fan run time
= $\Delta \text{Therms} * F_e * 29.3$

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 :

$$\begin{aligned}&= 78.3 * 0.0314 * 29.3 \\ &= 72.0 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND

$$\Delta kW = (\Delta k\text{Wh}_{\text{cooling}} / \text{FLH}_{\text{cooling}}) * CF$$

Where:

$\text{FLH}_{\text{cooling}}$ = Full load hours of air conditioning
= dependent on location¹¹⁰⁵:

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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

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:

$$\Delta kW_{SSP} = 39.4 / 570 * 0.68$$

$$= 0.047 \text{ kW}$$

$$\Delta kW_{PJM} = 39.4 / 570 * 0.466$$

$$= 0.032 \text{ kW}$$

NATURAL GAS SAVINGS

If Natural Gas heating:

$$\Delta \text{Therms} = [(((1/R_{\text{old_AG}} - 1/(R_{\text{added}} + R_{\text{old_AG}})) * L_{\text{basement_wall_total}} * H_{\text{basement_wall_AG}} * (1 - \text{Framing_factor}) + (1/(R_{\text{old_BG}} - 1/(R_{\text{added}} + R_{\text{old_BG}})) * L_{\text{basement_wall_total}} * (H_{\text{basement_wall_total}} - H_{\text{basement_wall_AG}}) * (1 - \text{Framing_factor})) * 24 * \text{HDD}) / (\eta_{\text{Heat}} * 100,000)] * \text{ADJ}_{\text{BasementHeat}}$$

η_{Heat} = 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 efficiency¹¹¹⁰
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:

$$= (((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0) + (1/8.67 - 1/(13 + 8.67)) * (20+25+20+25) * 4 * (1 - 0)) * 24 * 3079) / (0.72 * 100,000) * 0.60$$

$$= 78.3 \text{ therms}$$

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
η_{Cool}	Central AC	13 SEER
	Heat Pump	14 SEER
η_{Heat}	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 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 Crawl Space

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 boilers¹¹¹³. 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.

$$\Delta kWh = (\Delta kWh_{cooling} + \Delta kWh_{heating})$$

Where:

$\Delta kWh_{cooling}$	= If central cooling, reduction in annual cooling requirement due to insulation
	$= \left(\left(\left(\frac{1}{R_{old}} - \frac{1}{R_{added} + R_{old}} \right) * Area * (1 - Framing_factor) \right) * 24 * CDD * DUA \right) / (1000 * \eta_{Cool}) * ADJ_{FloorCool}$
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: $1 / [(0.85 \text{ cavity share of area} / (0.68 + 0.94 + 1.23 + 0.68)) + (0.15 \text{ framing share} / (0.68 + 7.5" * 1.25 \text{ R/in} + 0.94 + 1.23 + 0.68))] = 3.96$

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).

= 0.75¹¹²¹

1000 = Converts Btu to kWh

η_{Cool} = 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	η_{Cool} 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 savings¹¹²³.

= 80%

$\Delta kWh_{heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= $\left(\left(\left(\frac{1}{R_{old}} - \frac{1}{(R_{added} + R_{old})} \right) * Area * (1 - Framing_factor) * 24 * HDD \right) / (3,412 * \eta_{Heat}) \right) * ADJ_{FloorHeat}$

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

η_{Heat} = Efficiency of heating system

= Actual. If not available refer to default table below:¹¹²⁶

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (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

$ADJ_{\text{FloorHeat}}$ = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings¹¹²⁷.

= 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:

$$\begin{aligned}
 \Delta kWh &= (\Delta kWh_{\text{cooling}} + \Delta kWh_{\text{heating}}) \\
 &= (((1/3.96 - 1/(30+3.96)) * (20*25) * (1-0.12) * 24 * 281 * 0.75) / (1000 * 10.5)) * 0.8 + (((1/3.96 - 1/(30+3.96)) * (20*25) * (1-0.15) * 24 * 3079) / (3412 * 1.92)) * 0.6) \\
 &= (37.8 + 641.7) \\
 &= 679.5 \text{ kWh}
 \end{aligned}$$

$\Delta kWh_{\text{heating}}$ = If gas furnace heat, kWh savings for reduction in fan run time

= $\Delta \text{Therms} * F_e * 29.3$

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 (E_f in MMBtu/yr) and E_{ae} (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 crawlspce, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section):

$$\begin{aligned}\Delta\text{kWh} &= 60.4 * 0.0314 * 29.3 \\ &= 55.6 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = (\Delta\text{kWh_cooling} / \text{FLH_cooling}) * \text{CF}$$

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:

$$\Delta kW_{SSP} = 37.8 / 570 * 0.68$$

$$= 0.045 \text{ kW}$$

$$\Delta kW_{SSP} = 37.8 / 570 * 0.466$$

$$= 0.031 \text{ kW}$$

NATURAL GAS SAVINGS

If Natural Gas heating:

$$\Delta \text{Therms} = (1/R_{\text{old}} - 1/(R_{\text{added}} + R_{\text{old}})) * \text{Area} * (1 - \text{Framing_factor})) * 24 * \text{HDD} / (100,000 * \eta_{\text{Heat}}) * \text{ADJ}_{\text{FloorHeat}}$$

Where

η_{Heat} = 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 efficiency¹¹³⁴

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 72% efficient furnace:

$$\Delta \text{Therms} = ((1 / 3.96 - 1 / (30 + 3.96)) * (20 * 25) * (1 - 0.12) * 24 * 3079) / (100,000 * 0.72) * 0.60$$

$$= 60.4 \text{ therms}$$

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
η_{Cool}	Central AC	13 SEER
	Heat Pump	14 SEER
η_{Heat}	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 ¹¹³⁵.

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 boilers¹¹³⁷. 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.

$$\Delta kWh = (\Delta kWh_{cooling} + \Delta kWh_{heating})$$

Where

$$\Delta kWh_{cooling} = \text{If central cooling, reduction in annual cooling requirement due to wall insulation} \\ = (((1/R_{old} - 1/R_{wall}) * A_{wall} * (1 - \text{Framing_factor_wall})) * 24 * CDD * DUA) / (1000 * \eta_{Cool}) * ADJ_{WallCool}$$

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 assemblies¹¹⁴¹)

A_{wall} = Net area of insulated wall (ft²)

$\text{Framing_factor_wall}$ = 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).

= 0.75¹¹⁴⁵

1000 = Converts Btu to kBtu

η_{Cool} = 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	η_{Cool} 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 algorithms¹¹⁴⁷

= 80%

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to wall insulation

= $\left(\left(\left(\frac{1}{R_{old}} - \frac{1}{R_{wall}} \right) * A_{wall} * (1 - \text{Framing_factor_wall}) \right) * 24 * HDD \right) / (\eta_{Heat} * 3412) * ADJ_{WallHeat}$

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

η_{Heat} = 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	η_{Heat} (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 ft² of R-5 walls insulated to R-11, 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

$$\begin{aligned}
 \Delta \text{kWh} &= (\Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}}) \\
 &= (((((1/5 - 1/11) * 990 * (1-0.25)) * 842 * 0.75 * 24) / (1000 * 10.5)) * 80\%) + \\
 &\quad (((((1/5 - 1/11) * 990 * (1-0.25)) * 5113 * 24) / (1.92 * 3412)) * 60\%) \\
 &= 93.5 + 910 \\
 &= 1,004 \text{ kWh}
 \end{aligned}$$

$\Delta \text{kWh}_{\text{heating}}$ = If gas furnace heat, kWh savings for reduction in fan run time

= $\Delta \text{Therms} * F_e * 29.3$

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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

$$= 3.14\%^{1152}$$

$$29.3 = \text{kWh per therm}$$

For example, a single family home in Chicago with 990 ft² 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):

$$\begin{aligned}\Delta\text{kWh} &= 90.3 * 0.0314 * 29.3 \\ &= 83.1 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = (\Delta\text{kWh}_{\text{cooling}} / \text{FLH}_{\text{cooling}}) * \text{CF}$$

Where:

$$\begin{aligned}\text{FLH}_{\text{cooling}} &= \text{Full load hours of air conditioning} \\ &= \text{Dependent on location as below:}^{1153}\end{aligned}$$

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

$$\begin{aligned}\text{CF}_{\text{SSP}} &= \text{Summer System Peak Coincidence Factor for Central A/C (during system peak hour)} \\ &= 68\%^{1155}\end{aligned}$$

$$\begin{aligned}\text{CF}_{\text{SSP}} &= \text{Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)} \\ &= 72\%^{1156}\end{aligned}$$

$$\begin{aligned}\text{CF}_{\text{PJM}} &= \text{PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)} \\ &= 46.6\%^{1157}\end{aligned}$$

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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

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 ft² of R-5 walls insulated to R-11, 10.5 SEER Central AC, and 2.26 COP Heat Pump:

$$\begin{aligned}\Delta kW_{SSP} &= 93.5 / 570 * 0.68 \\ &= 0.11 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} &= 93.5 / 570 * 0.466 \\ &= 0.08 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If Natural Gas heating:

$$\Delta \text{Therms} = (((1/R_{\text{old}} - 1/R_{\text{wall}}) * A_{\text{wall}} * (1 - \text{Framing_factor_wall})) * 24 * \text{HDD}) / (\eta_{\text{Heat}} * 100,000 \text{ Btu/therm}) * \text{ADJ}_{\text{WallHeat}}$$

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

η_{Heat} = 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 ft² of R-5 walls insulated to R-11, with a gas furnace with system efficiency of 66%:

$$\begin{aligned}\Delta \text{Therms} &= (((1/5 - 1/11) * 990 * (1 - 0.25)) * 24 * 5113) / (0.66 * 100,000) * 60\% \\ &= 90.4 \text{ therms}\end{aligned}$$

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
η_{Cool}	Central AC	13 SEER
	Heat Pump	14 SEER
η_{Heat}	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 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 boilers¹¹⁶⁴. 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.

$$\Delta kWh = (\Delta kWh_{cooling} + \Delta kWh_{heating})$$

Where

$$\Delta kWh_{cooling} = \text{If central cooling, reduction in annual cooling requirement due to ceiling/attic insulation} \\ = (((1/R_{old} - 1/R_{attic}) * A_{attic} * (1 - \text{Framing_factor_attic})) * 24 * CDD * DUA) / (1000 * \eta_{Cool}) * ADJ_{AtticCool}$$

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 assemblies¹¹⁶⁸)

A_{attic} = Total area of insulated ceiling/attic (ft²)

$\text{Framing_factor_attic}$ = 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).

= 0.75¹¹⁷²

1000 = Converts Btu to kBtu

η_{Cool} = 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 following¹¹⁷³:

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 algorithms¹¹⁷⁴

= 121%

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

= $\left(\left(\left(\frac{1}{R_{old}} - \frac{1}{R_{attic}} \right) * A_{attic} * (1 - \text{Framing_factor_attic}) \right) * 24 * HDD \right) / (\eta_{Heat} * 3412) * ADJ_{AtticElectricHeat}$

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). *ComEd 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

η_{Heat} = Efficiency of heating system
= Actual (where new or where it is possible to measure or reasonably estimate). If not available refer to default table below¹¹⁷⁷:

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (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

$ADJ_{\text{AtticElectricHeat}}$ = Adjustment for electric heating savings to account for inaccuracies in engineering algorithms¹¹⁷⁸
= 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 ft² of attic insulation, completes air sealing, has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

$$\begin{aligned}
 \Delta \text{kWh} &= (\Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}}) \\
 &= (((((1/5 - 1/38) * 700 * (1-0.07)) * 842 * 0.75 * 24) / (1000 * 10.5)) * 121\%) + (((((1/5 - 1/38) * 700 * (1-0.07)) * 5113 * 24) / (1.92 * 3412)) * 60\%) \\
 &= 197 + 1,271 \\
 &= 1,468 \text{ kWh}
 \end{aligned}$$

$\Delta \text{kWh}_{\text{heating}}$ = If gas furnace heat, kWh savings for reduction in fan run time

$$= \Delta \text{Therms} * F_e * 29.3 * ADJ_{\text{AtticHeatFan}}$$

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). *ComEd 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 inaccuracies in engineering algorithms¹¹⁸⁰
= 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 ft² of attic insulation, completes air sealing, has a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section), and has pre and post attic insulation R-values of R-5 and R-38, respectively:

$$\begin{aligned}\Delta kWh &= 147 * 0.0314 * 29.3 * 107\% \\ &= 145 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh_{cooling} / FLH_{cooling}) * CF$$

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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

¹¹⁸⁰ As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). *ComEd 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 ft² of attic insulation, has 10.5 SEER Central AC and 2.26 COP Heat Pump, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

$$\begin{aligned}\Delta kW_{SSP} &= 197 / 570 * 0.68 \\ &= 0.24 \text{ kW} \\ \Delta kW_{PJM} &= 168 / 570 * 0.466 \\ &= 0.16 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If Natural Gas heating:

$$\Delta \text{Therms} = (((1/R_{\text{old}} - 1/R_{\text{attic}}) * A_{\text{attic}} * (1 - \text{Framing_factor_attic})) * 24 * \text{HDD}) / (\eta_{\text{Heat}} * 100,000 \text{ Btu/therm}) * \text{ADJ}_{\text{AtticGasHeat}}$$

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

η_{Heat} = Efficiency of heating system
= Equipment efficiency * distribution efficiency
= Actual¹¹⁸⁸ (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency¹¹⁸⁹.

$\text{ADJ}_{\text{AtticGasHeat}}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms¹¹⁹⁰

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). *ComEd 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 ft² of attic insulation, has a gas furnace with system efficiency of 66%, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

$$\begin{aligned}\Delta\text{Therms} &= (((1/5 - 1/38) * 700 * (1 - 0.07)) * 24 * 5113) / (0.66 * 100,000)) * 72\% \\ &= 151 \text{ therms}\end{aligned}$$

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
η_{Cool}	Central AC	13 SEER
	Heat Pump	14 SEER
η_{Heat}	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 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 boilers¹¹⁹³. 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.

$$\begin{aligned} CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \\ &= 68\%^{1194} \end{aligned}$$

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.

$$\Delta kWh = (\Delta kWh_{cooling} + \Delta kWh_{heating})$$

Where

$\Delta kWh_{cooling}$ = 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 assemblies¹¹⁹⁷)

A_{Rim} = Net area of insulated rim/band joist (ft²)

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).

= 0.75¹²⁰²

1000 = Converts Btu to kBtu

η_{Cool} = 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 following¹²⁰³:

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 savings¹²⁰⁴.

= 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

η_{Heat} = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate).
If not available refer to default table below¹²⁰⁷:

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (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

$ADJ_{\text{BasementHeat}}$ = Adjustment for basement wall and rim/band joist insulation to account for prescriptive engineering algorithms overclaiming savings¹²⁰⁸.

= 60%

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 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

$$\begin{aligned}
 \Delta \text{kWh} &= (\Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}}) \\
 &= (((1/5 - 1/13) * 100 * (1-0.05) * 281 * 24 * 0.75) / (1000 * 10.5)) + (((1/5 - 1/13) * 100 * (1-0.05) * 3079 * 24 * 0.60) / (1.92 * 3412)) \\
 &= 5.6 + 79.1 \\
 &= 84.7 \text{ kWh}
 \end{aligned}$$

$\Delta \text{kWh}_{\text{heating}}$ = 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%.

$$= \Delta \text{Therms} * F_e * 29.3$$

$$F_e = \text{Furnace Fan energy consumption as a percentage of annual fuel consumption} \\ = 3.14\%^{1209}$$

$$29.3 = \text{kWh per therm}$$

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):

$$\Delta \text{kWh} = 7.85 * 0.0314 * 29.3 \\ = 7.2 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = (\Delta \text{kWh}_{\text{cooling}} / \text{FLH}_{\text{cooling}}) * \text{CF}$$

Where:

$$\text{FLH}_{\text{cooling}} = \text{Full load hours of air conditioning} \\ = \text{Dependent on location as below:}^{1210}$$

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

$$\text{CF}_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Central A/C (during system peak hour)} \\ = 68\%^{1212}$$

$$\text{CF}_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)} \\ 72\%^{1213}$$

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

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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

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 ft² 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:

$$\begin{aligned}\Delta kW_{SSP} &= 5.6 / 570 * 0.68 \\ &= 0.0067 \text{ kW} \\ \Delta kW_{PJM} &= 5.6 / 570 * 0.466 \\ &= 0.0046 \text{ kW}\end{aligned}$$

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:

η_{Heat} = Efficiency of heating system
 = Equipment efficiency * distribution efficiency
 = Actual¹²¹⁵ (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency¹²¹⁶.

Other factors as defined above

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%:

$$\begin{aligned}\Delta \text{Therms} &= ((1/5 - 1/13) * 100 * (1-0.05) * 3079 * 24 * 0.60) / (0.66 * 100,000) \\ &= 7.85 \text{ therms}\end{aligned}$$

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
η_{Cool}	Central AC	13 SEER
	Heat Pump	14 SEER
η_{Heat}	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 years¹²¹⁹.

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 motor¹²²⁰.

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 0.831¹²²².

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS¹²²³

$$\begin{aligned}\Delta \text{kWh two speed} &= (((\text{Hrs/Day}_{\text{base}} * \text{GPM}_{\text{base}} * 60) / \text{EF}_{\text{base}}) - (((\text{Hrs/Day}_{2\text{spH}} * \text{GPM}_{2\text{spH}} * 60) + (\text{Hrs/Day}_{2\text{spL}} * \text{GPM}_{2\text{spL}} * 60)) / \text{WEF}_{2\text{sp}})) / 1000 * \text{Days} \\ \Delta \text{kWh variable speed} &= (((\text{Hrs/Day}_{\text{base}} * \text{GPM}_{\text{base}} * 60) / \text{EF}_{\text{base}}) - (((\text{Hrs/Day}_{\text{vsH}} * \text{GPM}_{\text{vsH}} * 60) / (\text{Hrs/Day}_{\text{vsL}} * \text{GPM}_{\text{vsL}} * 60)) / \text{WEF}_{\text{vs}})) / 1000 * \text{Days}\end{aligned}$$

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

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 below¹²²⁴:

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
= 125¹²²⁵

Based on the pool/pump application and the motor designation, the annual energy savings (Δ kWh) 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 SAVINGS¹²²⁶

$$\Delta kW \text{ two speed} = ((kWh/day_{base}) / (Hrs/day_{base}) - (kWh/day_{2sp}) / (Hr/day_{2sp})) * CF$$

$$\Delta kW \text{ variable speed} = ((kWh/day_{base}) / (Hrs/day_{base}) - (kWh/day_{vr}) / (Hr/day_{vr})) * CF$$

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

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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.