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2022 Illinois Statewide Technical Reference Manual for Energy Efficiency

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Volume 3: Residential Measures

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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 30 Clean Air Delivery Rate (CADR) for Smoke[1] to be considered under this specification. Minimum Performance Requirement is expressed in Smoke CADR/Watt and it shall be greater than or equal to the Minimum Smoke CADR/Watt Requirement shown in the table below:

CADR Range	CADR/W
30 ≤ Smoke CADR < 100	1.90
100 ≤ Smoke CADR < 150	2.40
150 ≤ Smoke CADR < 200	2.90
200 ≤ Smoke CADR	2.90

- "Partial On Mode" Requirements are to be calculated as per Section 3.4.1 of the Energy Star Eligibility Criteria [2]
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a conventional unit[3] that does not meet ENERGY STAR Efficiency Requirements.[4]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 9 years.[5]

DEEMED MEASURE COST

The incremental cost for this measure is dependent on the Air Purifier size in CADR of Smoke. [6]

[1] Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard
[2] ENERGY STAR® Product Specification for Room Air Cleaners - Eligibility Criteria Version 2.0, effective October 17, 2020.
[3] As defined in ENERGY STAR v.2.0 Room Air Cleaners Data Package and analysis. See file: ICF_EPA_AirPurifier_Summary Savings Calculations.xlsx.
[4] ENERGY STAR® Product Specification for Room Air Cleaners - Eligibility Criteria Version 2.0.
[5] ENERGY STAR Qualified Room Air Cleaner Calculator citing Appliance Magazine, Portrait of the U.S. Appliance Industry 1998.
[6] ENERGY STAR V2 Room Air Cleaners Data Package (October 11, 2019). See file "ENERGY STAR V2 Room Air Cleaners Data Package_GH 05122020_VEIC.xlsx"

Product Size	Minimum CADR/W	Average Purchase Cost ($)	Average Incremental Cost ($)
30 ≤ Smoke CADR < 100	1.90	$82.49	$8.44
100 ≤ Smoke CADR < 150	2.40	$140.43	$22.33
150 ≤ Smoke CADR < 200	2.90	$349.00	$92.34
200 ≤ Smoke CADR	2.90	$264.49	$44.50

LOADSHAPE

Loadshape C53 – Flat

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = kWh_base – kWh_eff

kWh_base = hours * (SmokeCADR_base / (SmokeCADR_per_watt_base * 1000)) + (8760 - hours) * PartialOnModePower_base / 1000)

kWh_eff = hours * (SmokeCADR_eff / (SmokeCADR_per_watt_eff * 1000)) + (8760 - hours) * PartialOnModePower_eff / 1000)

Where:

kWh_base = Annual Electrical Usage for baseline unit (kWh)

kWh_eff = Annual Electrical Usage for efficient unit (kWh)

hours = Annual active operating hours

= 5840[7]

SmokeCADR_base = Smoke CADR for baseline units, as provided in table below

SmokeCADR_per_watt_base = Smoke CADR delivery rate per watt for baseline units, as provided in table below

PartialOnModePower_base = Partial On Model Power for baseline units by category (watts), as provided in table below

1000 = Conversion factor from watts to kilowatts

SmokeCADR_eff = Smoke CADR for efficient unit

= Actual, if unknown use values provided in table below

SmokeCADR_per_watt_eff = Smoke CADR delivery rate per watt for efficient units

= Actual, if unknown use values provided in table below

PartialOnModePower_eff = Partial On Model Power for efficient units by category (watts)

[7] Consistent with ENERGY STAR v.2.0 Room Air Cleaners Data Package and analysis. See file: ICF_EPA_AirPurifier_Summary Savings Calculations.xlsx.

= Actual, if unknown use values provided in table below

Parameter assumptions for units by CADR Range:[8]

CADR Range	Smoke CADR	Smoke CADR per Watt	Partial On Mode Power (watts)	Annual Energy Use (kWh)
	Baseline Units			
30 ≤ Smoke CADR < 100	83.3	1.64	2.0	302
100 ≤ Smoke CADR < 150	127.6	1.83	2.0	413
150 ≤ Smoke CADR < 200	175.2	1.94	2.0	533
200 ≤ Smoke CADR	292.9	1.89	2.0	911
	Efficient Units			
30 ≤ Smoke CADR < 100	83.3	2.90	0.478	169
100 ≤ Smoke CADR < 150	127.6	4.08	0.325	184
150 ≤ Smoke CADR < 200	175.2	4.47	0.562	231
200 ≤ Smoke CADR	292.9	5.05	0.638	341

CADR Range	Energy Savings ΔkWh
30 ≤ Smoke CADR < 100	133
100 ≤ Smoke CADR < 150	229
150 ≤ Smoke CADR < 200	303
200 ≤ Smoke CADR	570

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5840 hours[9]

CF = Summer Peak Coincidence Factor for measure

= 66.7%[10]

CADR Range	ΔkW
30 ≤ Smoke CADR < 100	0.015
100 ≤ Smoke CADR < 150	0.026

[8] Baseline values are consistent with ENERGY STAR v.2.0 Room Air Cleaners Data Package and analysis. See file: ICF_EPA_AirPurifier_Summary Savings Calculations.xlsx. Efficient values are averages within each CADR range for all models on the ENERGY STAR Qualified products list (QPL accessed: February 18, 2021). Both Baseline & Efficienct Capacities (CADR) are also sourced from the ENERGY STAR QPL. For Final Savings Calcs for this measure please see: IL TRM_AirPurifier_Summary Savings Calculations_06152021.xlsx.

[9] Consistent with ENERGY STAR v.2.0 Room Air Cleaners Data Package and analysis. See file: ICF_EPA_AirPurifier_Summary Savings Calculations.xlsx.

[10] Assumes that the purifier usage is evenly spread throughout the year, therefore coincident peak is calculated as 5840/8760 = 66.7%.

CADR Range	ΔkW
150 ≤ Smoke CADR < 200	0.035
200 ≤ Smoke CADR	0.065

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

There are no operation and maintenance cost adjustments for this measure.[11]

MEASURE CODE: RS-APL-ESAP-V05-220101

REVIEW DEADLINE: 1/1/2024

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

5.1.2 ENERGY STAR Clothes Washers

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard sized clothes washer meeting the minimum federal baseline as of January 2018.[12]

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years[13]

DEEMED MEASURE COST

The incremental cost for an ENERGY STAR unit is assumed to be $84 and for a CEE Tier 2 unit it is $141.[14]

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape R01 - Residential Clothes Washer

COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%.[15]

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

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

[14] Cost estimates are based on Navigant analysis for the Department of Energy (see IL_TRM_CW Analysis_06202019.xlsx). 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.

[15] 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"* .[16]

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

IMEFsavings[17] = Capacity * (1/IMEFbase - 1/IMEFeff) * Ncycles

Where

Capacity = Clothes Washer capacity (cubic feet)

= Actual. If capacity is unknown assume 3.50 cubic feet [18]

IMEFbase = Integrated Modified Energy Factor of baseline unit

= 1.75[19]

IMEFeff = Integrated Modified Energy Factor of efficient unit

= Actual. If unknown assume average values provided below.

Ncycles = Number of Cycles per year

= 295[20]

IMEFsavings is provided below based on deemed values:[21]

Efficiency Level	IMEF	IMEF Savings (kWh)
Federal Standard	1.75	0.0
ENERGY STAR	2.23	126.0

[16] Definition provided on the ENERGY STAR website.
[17] IMEFsavings represents total kWh only when water heating and drying are 100% electric.
[18] 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.
[19] 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).
[20] Weighted average of clothes washer cycles per year (based on 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, state of Illinois. 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.
[21] 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 "IL TRM_CW Analysis_06202019.xlsx" for the calculation.

Efficiency Level	IMEF	IMEF Savings (kWh)
CEE Tier 2	2.92	235.8

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

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

Where:

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

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

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

	Percentage of Total Energy Consumption[22]		
	%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	16%[23]

%Electric_Dryer = Percentage of dryer savings assumed to be electric

Dryer fuel	%Electric_Dryer
Electric	100%
Natural Gas	0%
Unknown	38%[24]

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

[22] 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 "IL TRM_CW Analysis_06202019.xlsx" for the calculation.

[23] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of 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.

[24] Default assumption for unknown is based on percentage of homes with electric dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of 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.

	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	126.0	114.6	32.5	21.0	68.3	56.8	116.3	22.8	58.6
CEE Tier 2	235.8	113.9	120.9	-1.0	164.9	43.0	132.9	18.0	61.9

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

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

Where

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

=5,010[25]

Using defaults provided:

ENERGY STAR ΔkWh_{water} = 1,259/1,000,000 * 5,010

= 6.3 kWh

ENERGY STAR Most Efficient ΔkWh_{water} = 2,157/1,000,000 * 5,010

= 10.8 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

Hours = Assumed Run hours of Clothes Washer

= 295 hours[26]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[27]

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

[25] 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'.

[26] Based on a weighted average of 295 clothes washer cycles per year assuming an average load runs for one hour (2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, data for the state of Illinois)

[27] 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	0.0088	0.0073	0.0150	0.0029	0.0075
CEE Tier 3	0.0304	0.0147	0.0156	-0.0001	0.0212	0.0055	0.0171	0.0023	0.0080

NATURAL GAS SAVINGS

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

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

Where:

Therm_convert = Convertion factor from kWh to Therm

= 0.03412

R_eff = Recovery efficiency factor

= 1.26[28]

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

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[29]

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

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%
Unknown	62%[30]

Other factors as defined above.

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

[28] 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.

[29] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of 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

[30] Default assumption for unknown fuel is based on percentage of homes with gas dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of 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.

	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	0.5	3.2	3.7	2.0	2.5	0.4	3.6	2.4
CEE Tier 3	0.0	5.2	3.9	9.2	7.7	7.7	4.4	8.3	6.8

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Where

ΔWater (gallons) = Water saved, in gallons

IWFbase = Integrated Water Factor of baseline clothes washer

= 5.29[31]

IWFeff = Water Factor of efficient clothes washer

= Actual. If unknown assume average values provided below.

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

Efficiency Level	IWF[32]	ΔWater (gallons per year)
Federal Standard	5.29	0.0
ENERGY STAR	4.04	1,295
ENERGY STAR Most Efficient	3.20	2,157

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESCL-V09-220101

REVIEW DEADLINE: 1/1/2023

[31] 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).

[32] 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 “IL TRM_CW Analysis_06202019.xlsx” 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 5.0 (effective 10/31/2019) and ENERGY STAR Most Efficient 2020 Criteria (effective 01/01/2020) 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:

Equipment Specification	Product Capacity	ENERGY STAR Criteria	ENERGY STAR Most Efficient Criteria
	(Pints/Day)	(L/kWh)	(L/kWh)
Portable Dehumidifier	≤ 25	≥1.57	≥1.70
	>25 and ≤ 50	≥1.80	≥1.90
	>50 and < 155	≥3.30	≥3.40

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate. The Whole – Home option for Dehumidifiers was not included, due to the extremely limited availability of Qualified products on the market. As of May 5, 2020, there are zero models.

DEFINITION OF BASELINE EQUIPMENT

The baseline for this measure is defined as a new dehumidifier that meets the Code of Federal Regulations appliance federal efficiency standards. As of June 13, 2019, those are as defined below for Dehumidifiers:

Equipment Specification	Capacity (pints/day)	Federal Standard Criteria (L/kWh)
Portable Dehumidifier	≤25	≥1.30
	>25 and ≤ 50	≥1.60
	>50 and <155	≥2.80

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the measure is 12 years.[33] Analysis period is the same as the lifetime.

DEEMED MEASURE COST

The incremental cost is the difference in cost between a baseline and an ENERGY STAR qualified unit. Please see the table below for cost assumptions used:

33 EPA Research, 2012; ENERGY STAR Appliance Calculator, Dehumidifier Section

Equipment Specification	ENERGY STAR	ENERGY STAR Most Efficient
Portable Dehumidifier	$10[34]	$75[35]

LOADSHAPE

Loadshape R12 - Residential - Dehumidifier

COINCIDENCE FACTOR

The coincidence factor is assumed to be 50%.[36]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

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

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

0.473 = Constant to convert Pints to Liters

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

Hours = Run hours per year

= 2,200[37]

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

Annual kWh usage and savings, for each capacity class and product type, are presented in the four tables below:

Portable Dehumidifiers					Annual kWh		
Capacity Range (pints/day)	Capacity Used[38] (pints/day)	Federal Standard Criteria (≥ L/kWh)	ENERGY STAR Criteria (≥ L/kWh)	ENERGY STAR Most Efficient (≥ L/kWh)	Federal Standard	ENERGY STAR	ENERGY STAR Most Efficient
≤25	20	1.30	1.57	1.70	667	552	510
>25 and ≤50	37.5	1.60	1.80	1.90	1016	903	856
>50 and <155	102.5	2.80	3.30	3.40	1587	1347	1307
Average[39]	38.9	1.54	1.75	1.86	1095	962	907

[34] Based on incremental costs sourced from the 2016 ENERGY STAR Appliance Calculator and weighted by capacity based on ENERGY STAR qualified products, accessed on May 2019.

[38] Capacity Used in calculations for each bin is an average. See next footnote regarding overall average for Portable Dehumidifiers

Portable Dehumidifier		Energy Savings (ΔkWh)	
Capacity Range (pints/day)	Capacity Used (pints/day)	ENERGY STAR	ENERGY STAR Most Efficient
≤25	20	115	157
>25 and ≤50	37.5	113	160
>50 and <155	102.5	241	280
Average	38.9	*134*	*188*

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.50[40]

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

Portable Dehumidifier	Annual Summer Peak Savings (ΔkW)	
Capacity Range (pints/day)	ENERGY STAR	ENERGY STAR Most Efficient
≤25	0.026	0.036
>25 and ≤50	0.026	0.037
>50 and <155	0.055	0.064
Average	0.030	0.043

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[36] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). With 2,200 operating hours, coincidence peak during summer peak is therefore 2200/4392 = 50.1%

[37] Based on Mattison et al., "Dehumidifiers: A Major Consumer of Residential Electricity", Cautley et al., "Dehumidification and Subslab Ventilation in Wisconsin Homes" and Yang et al., "Dehumidifier Use in the U.S. Residential Sector", all indicating average usage around 2,200 hours per year.

[38] Capacity Used in calculations for each bin is an average. See next footnote regarding overall average for Portable Dehumidifiers

[39] Weighted Overall average based on ENERGY STAR Products List 2020 for Dehumidifiers, accessed May 2020. See sheet *ESTAR-2020-5* in file "ENERGY STAR Dehumidifier TRM Analysis_2021.xlsx"

[40] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). With 2200 operating hours, coincidence peak during summer peak is therefore 2200/4392 = 50.1%

MEASURE CODE: RS-APL-ESDH-V09-220101

REVIEW DEADLINE: 1/1/2025

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 6.0, 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[41]	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 years.[42]

DEEMED MEASURE COST

The incremental cost for standard and compact dishwashers is provided in the table below:[43]

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

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[41] The 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". As of July 2021, Version 7.0 specification is still under development. 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.

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

[43] 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%.[44]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh^{45} = ((kWh_{Base} - kWh_{ESTAR}) * (\%kWh\_op + (\%kWh\_heat * \%Electric\_DHW)))$$

Where:

kWh_{BASE} = Baseline kWh consumption per year

Dishwasher Type	Maximum kWh/year
Standard	307
Compact	222

kWh_{ESTAR} = ENERGY STAR kWh annual consumption

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

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

= 100 - 56%[46]

= 44%

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

= 56%[47]

%Electric_DHW = Percentage of DHW savings assumed to be electric

DHW fuel	%Electric_DHW
Electric	100%

[44] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.
[45] 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.
[46] ENERGY STAR Qualified Appliance Savings Calculator, last updated October 2016.
[47] Ibid.

DHW fuel	%Electric_DHW
Natural Gas	0%
Unknown	16%[48]

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

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

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

Where

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

=5,010[49]

Using defaults provided:

Standard ΔkWh_{water} = 252/1,000,000 * 5,010

= 1.3 kWh

Compact ΔkWh_{water} = 67/1,000,000 * 5,010

= 0.3 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS[50]

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

Where:

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

Hours = Annual operating hours[51]

48 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.

49 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'.

50 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.

51 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.

= 353 hours

CF = Summer Peak Coincidence Factor

= 2.6% [52]

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

NATURAL GAS SAVINGS

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

Where

%kWh_heat = % of dishwasher energy used for water heating

= 56%

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

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[53]

R_eff = Recovery efficiency factor

= 1.26[54]

0.03412 = factor to convert from kWh to Therm

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Where

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

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

[53] 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.

[54] 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.

Dishwasher Type	$Water_{Base}$ (gallons) [55]
Standard	840
Compact	588

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

Dishwasher Type	$Water_{EFF}$ (gallons) [56]
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-V07-220101

REVIEW DEADLINE: 1/1/2023

[55] 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.
[56] Ibid

5.1.5 ENERGY STAR Freezer

DESCRIPTION

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

Product Category	Volume (cubic feet)	Assumptions after September 2014	
		Federal Baseline Maximum Energy Usage in kWh/year[57]	ENERGY STAR Maximum Energy Usage in kWh/year[58]
Upright Freezers with Manual Defrost	7.75 or greater	5.57*AV + 193.7	5.01*AV + 174.3
Upright Freezers with Automatic Defrost	7.75 or greater	8.62*AV + 228.3	7.76*AV + 205.5
Chest Freezers and all other Freezers except Compact Freezers	7.75 or greater	7.29*AV + 107.8	6.56*AV + 97.0
Compact Upright Freezers with Manual Defrost	< 7.75 and 36 inches or less in height	8.65*AV + 225.7	7.79*AV + 203.1
Compact Upright Freezers with Automatic Defrost	< 7.75 and 36 inches or less in height	10.17*AV + 351.9	9.15*AV + 316.7
Compact Chest Freezers	<7.75 and 36 inches or less in height	9.25*AV + 136.8	8.33*AV + 123.1

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

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

DEFINITION OF BASELINE EQUIPMENT

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

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[57] See Department of Energy Federal Standards.

[58] See Version 5.0 ENERGY STAR specification.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 22 years.[59]

DEEMED MEASURE COST

The incremental cost for this measure is $35.[60]

LOADSHAPE

Loadshape R04 - Residential Freezer

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 95%.[61]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS:

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

Where:

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

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

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

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

If volume is unknown, use the following default values:

Product Category	Volume Used[62]	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

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[59] Based on 2011 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[60] 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.
[61] Based on eShapes Residential Freezer load data as provided by Ameren.
[62] Volume is based on ENERGY STAR Calculator assumption of 16.14 ft^3 average volume, converted to Adjusted volume by multiplying by 1.73.

Product Category	Volume Used[62]	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

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Full Load hours per year

= 5890[63]

CF = Summer Peak Coincident Factor

= 0.95 [64]

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

$$\Delta kW = 26.9/5890 * 0.95$$
$$= 0.0043\ kW$$

If volume is unknown, use the following default values:

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

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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

[64] Based on eShapes Residential Freezer load data as provided by Ameren.

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

REVIEW DEADLINE: 1/1/2023

5.1.6 ENERGY STAR and CEE Tier 2 Refrigerator

DESCRIPTION

This measure relates to:

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

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

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

Product Category	Existing Unit	Assumptions after September 2014	
	Based on Refrigerator Recycling algorithm	Federal Baseline Maximum Energy Usage in kWh/year[65]	ENERGY STAR Maximum Energy Usage in kWh/year[66]
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.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a refrigerator meeting the efficiency specifications of ENERGY STAR or CEE Tier

65 See Department of Energy Federal Standards.

66 See Version 5.0 ENERGY STAR specification.

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

DEFINITION OF BASELINE EQUIPMENT

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

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 17 years.[67]

Remaining life of existing equipment is assumed to be 6 years.[68]

DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit[69] and $140 for a CEE Tier 2 unit.[70]

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable, assume $451 for ENERGY STAR unit and $551 for CEE Tier 2 unit.[71]

The avoided replacement cost (after 4 years) of a baseline replacement refrigerator is $413.[72] This cost should be discounted to present value using the nominal societal discount rate.

LOADSHAPE

Loadshape R05 - Residential Refrigerator

COINCIDENCE FACTOR

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS:

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

[67] Based on 2011 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[68] Standard assumption of one third of effective useful life.
[69] From ENERGY STAR calculator linked above.
[70] 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.
[71] 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.
[72] Calculated using incremental cost from Time of Sale measure and applying inflation rate of 1.91%.

Early Replacement:

ΔkWh for remaining life of existing unit (1st 6 years) $= UEC_{EXIST} – UEC_{EE}$

ΔkWh for remaining measure life (next 11 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 15% lower than baseline.

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8:[73]

Assumptions after standard changes on September 1st, 2014:

Product Category	Existing Unit UEC_{EXIST} [74]	New Baseline UEC_{BASE}	New Efficient UEC_{EE}		Early Replacement (1st 6 years) ΔkWh		Time of Sale and Early Replacement (last 11 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	313.3	696.1	714.5	36.9	55.3
2. Refrigerator-Freezer--partial automatic defrost	1027.7	430.9	387.8	366.3	640.0	661.5	43.1	64.6
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	375.4	417.2	439.1	44.3	66.2
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	1241.0	517.1	465.4	439.5	775.6	801.4	51.7	77.6
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	814.5	545.1	490.7	463.3	323.9	351.2	54.4	81.8
5A Refrigerator-freezer—automatic defrost with	814.5	713.8	651.0	606.7	163.6	207.8	62.8	107.1

[73] Volume is based on the ENERGY STAR calculator average assumption of 14.75 ft^3 fresh volume and 6.76 ft^3 freezer volume.
[74] 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} [74]	New Baseline UEC_{BASE}	New Efficient UEC_{EE}		Early Replacement (1st 6 years) ΔkWh		Time of Sale and Early Replacement (last 11 years) ΔkWh	
			ENERGY STAR	CEE T2	ENERGY STAR	CEE T2	ENERGY STAR	CEE T2
bottom-mounted freezer with through-the-door ice service								
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	814.5	601.9	550.1	511.6	264.4	303.0	51.7	90.3
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	1241.0	652.9	596.1	554.9	644.9	686.0	56.8	97.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

TAF = Temperature Adjustment Factor

= 1.25 [75]

LSAF = Load Shape Adjustment Factor

= 1.057 [76]

If volume is unknown, use the following defaults:

[75] 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).

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

Product Category	Assumptions after September 2014 standard change ΔkW			
	Early Replacement (1st 6 years)		Time of Sale and Early Replacement (last 11 years)	
	ENERGY STAR	CEE T2	ENERGY STAR	CEE T2
1. Refrigerators and Refrigerator-freezers with manual defrost	0.105	0.108	0.006	0.008
2. Refrigerator-Freezer--partial automatic defrost	0.096	0.100	0.006	0.010
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	0.063	0.066	0.007	0.010
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	0.117	0.121	0.008	0.012
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	0.049	0.053	0.008	0.012
5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	0.025	0.031	0.009	0.016
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	0.040	0.046	0.008	0.014
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	0.097	0.103	0.009	0.015

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-V08-200101

REVIEW DEADLINE: 1/1/2023

5.1.7 ENERGY STAR and CEE Tier 2 Room Air Conditioner

DESCRIPTION

This measure relates to:

a) Time of Sale the purchase and installation of a room air conditioning unit that meets CEE Tier 1 (equivalent to ENERGY STAR version 4.0, which is effective October 26^{th} 2015[77]) or CEE Tier 2 minimum qualifying efficiency specifications, in place of a baseline unit. The baseline is based on the Federal Standard effective June 1^{st}, 2014.

Product Type and Class (Btu/hr)		Federal Standard with louvered sides (CEER)[78]	Federal Standard without louvered sides (CEER)	ENERGY STAR v4.0 / CEE Tier 1 with louvered sides (CEER)[79]	ENERGY STAR v4.0 / CEE Tier 1without louvered sides (CEER)	CEE Tier 2 (CEER)[80]
Without Reverse Cycle	< 8,000	11.0	10.0	12.1	11.0	12.7
	8,000 to 10,999	10.9	9.6	12.0	10.6	12.5
	11,000 to 13,999	10.9	9.5	12.0	10.5	12.5
	14,000 to 19,999	10.7	9.3	11.8	10.2	12.3
	20,000 to 27,999	9.4	9.4	10.3	10.3	10.8
	>=28,000	9.0	9.4	9.9	10.3	10.4
With Reverse Cycle	<14,000	9.8	9.3	10.8	10.2	12.5
	14,000 to 19,999	9.8	8.7	10.8	9.6	12.3
	>=20,000	9.3	8.7	10.2	9.6	10.4
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.

a) 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 or CEE Tier 1 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.

77 ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
78 See DOE's Appliance and Equipment Standards for Room AC;
79 ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
80 The Consortium for Energy Efficiency Super Efficient Home Appliance Initiative, Room Air Conditioner Specification, CEE Advanced Tier (CEER), effective January 31, 2017. Please see file "CEE_ResApp_RoomAirConditionerSpecification_2017.pdf". https://library.cee1.org/system/files/library/13069/CEE_ResApp_RoomAirConditionerSpecification_2017.pdf

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the new room air conditioning unit must meet the CEE Tier 1 (ENERGY STAR version 4.0 which is effective October 26th 2015[81]) efficiency standards presented above.

DEFINITION OF BASELINE EQUIPMENT

Time of Sale: the baseline assumption is a new room air conditioning unit that meets the Federal Standard (effective June 1st, 2014)[82] efficiency standards as presented above.

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years.[83]

Remaining life of existing equipment is assumed to be 4 years.[84]

DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $40 for a CEER Tier 1 or ENERGY STAR unit and $100 for a CEE Tier 2 unit.[85]

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable assume $448 for CEE Tier 1 or ENERGY STAR unit and $508 for CEE Tier 2 unit.[86]

The avoided replacement cost (after 4 years) of a baseline replacement unit is $432.[87] This cost should be discounted to present value using the nominal societal discount rate.

LOADSHAPE

Loadshape R08 - Residential Cooling

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.3.[88]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

81 ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
82 See DOE's Appliance and Equipment Standards for Room AC.
83 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
84 Standard assumption of one third of effective useful life.
85 CEE Tier 1 cost based on field study conducted by Efficiency Vermont and Tier 2 based on professional judgement.
86 CEE Tier 1 based on IL PHA Efficient Living Program Data for 810 replaced units showing $416 per unit plus $32 average recycling/removal cost. Differential in cost for the CEE Tiers is $60, therefore CEE Tier 2 is $448 + 60 = $508.
87 Estimate based upon Time of Sale incremental costs and applying inflation rate of 1.91%.
88 Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

Early Replacment:

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

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

Where:

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

= dependent on location:[89]

Climate Zone (City based upon)	FLH_{RoomAC}
1 (Rockford)	220
2 (Chicago)	210
3 (Springfield)	319
4 (Belleville)	428
5 (Marion)	374
Weighted Average[90]	248

Btu/H = Size of rebated unit

= Actual. If unknown assume 8500 Btu/hr[91]

EERexist =Efficiency of existing unit

= Actual. If unknown assume 7.7 [92]

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption)[93]

CEERbase = Combined Energy Efficiency Ratio of baseline unit

= As provided in tables above

CEERee = Combined Energy Efficiency Ratio of CEE Tier 1 or ENERGY STAR unit

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

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

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

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

[92] Based on Nexus Market Research Inc, RLW Analytics, December 2005; “Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report.”

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

Time of Sale:

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

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

= 17.7 kWh

Early Replacement:

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

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

= 137.3 kWh

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

= 24.1 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

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

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[94]

1.01 = Factor to convert CEER to EER (CEER includes standby and off power consumption)[95]

Other variable as defined above

Time of Sale:

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

$\Delta kW_{CEE\ TIER\ 1}$ = (8500 * (1/(10.9 * 1.01) – 1/(12.0*1.01))) / 1000 * 0.3

= 0.021 kW

Early Replacement:

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

ΔkW for remaining life of existing unit (1st 4 years) = (9000 * (1/7.7 - 1/(12.0 * 1.01)))/1000 * 0.3

= 0.128 kW

ΔkW for remaining measure life (next 8 years) = (9000 * (1/(10.9 * 1.01) - 1/(12.0 * 1.01)))/1000 * 0.3

= 0.022 kW

NATURAL GAS SAVINGS

N/A

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

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESRA-V08-220101

REVIEW DEADLINE: 1/1/2025

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.[96]

Deemed Measure Cost

Measure cost includes the customer's value placed on their lost amenity, any customer transaction costs, and the cost of pickup and recycling of the refrigerator/freezer and should be based on actual costs of running the program. The payment (bounty) a Program Administrator makes to the customer serves as a proxy for the value the customer places on their lost amenity and any customer transaction costs. If unknown assume $170 per unit.[97]

Loadshape

Loadshape R05 - Residential Refrigerator

Coincidence Factor

The coincidence factor is assumed 1.081 for Refrigerators and 1.028 for Freezers[98].

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

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

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

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS[99]

Refrigerators:

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

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

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

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

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

(= 1 if Primary, else 0)

Interaction: Located in Unconditioned Space x CDD/365.25

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

CDD = Cooling Degree Days

= Dependent on location:[101]

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

[99] 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.

[100] 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".

[101] 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:[102]

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

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used.[103] For illustration purposes, this example uses 0.93.[104]

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

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

= 969 * 0.93

= 900.9 kWh

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients:[105]

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
Interaction: Located in Unconditioned Space x	9.778

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

[103] 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.

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

[105] 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
CDD/365.25	
Interaction: Located in Unconditioned Space x HDD/365.25	-12.755

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

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

Interaction: Located in Unconditioned Space x CDD/365.25

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

CDD = Cooling Degree Days (see table above)

Interaction: Located in Unconditioned Space x HDD/365.25

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

HDD = Heating Degree Days (see table above)

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used.[106] For illustration purposes, the example uses 0.85.[107]

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

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

= 977 * 0.825

= 905 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = kWh/8766 * CF

Where:

kWh = Savings provided in algorithm above

CF = Coincident factor defined as summer kW/average kW

= 1.081 for Refrigerators

= 1.028 for Freezers[108]

[106] 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.

[107] Most recent freezer part-use factor from Ameren Illinois Company PY5 evaluation.

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

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

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

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RFRC-V08-220101

REVIEW DEADLINE: 1/1/2024

5.1.9 Room Air Conditioner Recycling

DESCRIPTION

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed remaining useful life of the existing room air conditioning unit being retired is 4 years.[109]

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%.[110]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

[109] A third of assumed measure life for Room AC.
[110] Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

Where:

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

= dependent on location:[111]

Climate Zone (City based upon)	FLH_{RoomAC}
1 (Rockford)	220
2 (Chicago)	210
3 (Springfield)	319
4 (Belleville)	428
5 (Marion)	374
Weighted Average[112]	248

Btu/H = Size of retired unit

= Actual. If unknown assume 8500 Btu/hr [113]

EERexist = Efficiency of existing unit

= 9.8[114]

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

ΔkWh = ((319 * 8500 * (1/9.8)) / 1000)

= 276 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (Btu/hr * (1/EERexist))/1000) * CF$$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[115]

For example, an 8500 Btu/h unit:

ΔkW = (8500 * (1/9.8)) / 1000) * 0.3

= 0.26 kW

---

111 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.

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

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

114 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.

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

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RARC-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 heat pump technology, increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers[116]. 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 or ENERGY STAR Most Efficient criteria, as required by the program.

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years.[117]

DEEMED MEASURE COST

The incremental cost for an ENERGY STAR clothes dryer is assumed to be $152 and $405 for an ENERGY STAR Most Efficient dryer.[118]

LOADSHAPE

Loadshape R17 - Residential Electric Dryer

COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%.[119]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

Where:

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

Dryer Size	Load (lbs)[120]
Standard	8.45
Compact	3

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis.[121] If product class unknown, assume electric, standard.

Product Class	CEF (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft^3)	3.11
Vented Electric, Compact (120V) (< 4.4 ft^3)	3.01
Vented Electric, Compact (240V) (<4.4 ft^3)	2.73
Ventless Electric, Compact (240V) (<4.4 ft^3)	2.13
Vented Gas	2.84[122]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR or ENERGY STAR Most Efficient requirements.[123] If product class unknown, assume electric, standard.

	ENERGY STAR	ENERGY STAR Most Efficient
Product Class	CEF (lbs/kWh)	CEF (lbs/kWh)
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	3.93	4.3
Vented or Ventless Electric, Compact (120V) (< 4.4 ft^3)	3.80	4.3
Vented Electric, Compact (240V) (< 4.4 ft^3)	3.45	4.3
Ventless Electric, Compact (240V) (< 4.4 ft^3)	2.68	3.7
Vented Gas	3.48[124]	3.8

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year.[125]

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 16% for gas dryers[126]

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120 Based on ENERGY STAR test procedures.

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

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

123 ENERGY STAR Clothes Dryers Key Product Criteria.

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

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

126 %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.

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

ΔkWh = ((8.45/3.11 – 8.45/3.93) * 283 * 100%)

= 160 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer. Use actual data if available. If unknown, use 283 hours per year.[127]

CF = Summer Peak Coincidence Factor for measure

= 3.8%[128]

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

ΔkW = 160/283 * 3.8%

= 0.0215 kW

NATURAL GAS SAVINGS

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

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

Where:

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

%Gas = Percent of overall savings coming from gas

= 0% for electric units and 84% for gas units[129]

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

ΔTherm = (8.45/2.84 – 8.45/3.48) * 283 * 0.03412 * 0.84

= 4.44 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[127] ENERGY STAR qualified dryers have a maximum test cycle time of 80 minutes. Assume one hour per dryer cycle.
[128] Based on coincidence factor of 3.8% for clothes washers.
[129] %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.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESDR-V04-210101

REVIEW DEADLINE: 1/1/2023

5.1.11 ENERGY STAR Water Coolers

DESCRIPTION

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for a water cooler is 10 years.[130]

DEEMED MEASURE COST

The incremental cost for this measure is estimated at $17.[131]

LOADSHAPE

Loadshape C53: Flat

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 1.0.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

kWh_{base} = Daily energy use (kWh/day) for baseline water cooler[132]

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

[130] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
[131] Ameren Missouri PY3 Evaluation Report.
[132] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.

kWh_{ee} = Daily energy use (kWh/day) for ENERGY STAR water cooler[133]

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

Days = Number of days per year that the water cooler is in use
= 365.25 days[134]

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 = ΔkWh / Hours * CF

Where:

Hours = Number of hours per year water cooler is in use
= 8766 hours[135]

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

---

[133] Average kWh/day for from the ENERGY STAR efficient product database.
[134] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
[135] 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) or washing machines located in multifamily building common areas. The system generates ozone (O_3), a naturally occurring molecule, which helps clean fabrics by chemically reacting with soils in cold water. Adding an ozone laundry system(s) eliminate the use of chemicals, detergents, and hot water by residential washing machine(s).

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

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

DEFINITION OF EFFICIENT EQUIPMENT

A new, single-unit 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.[136]

DEEMED MEASURE COST

The deemed measure cost is $300 for a new single-unit ozone laundry system.[137]

LOADSHAPE

Loadshape R01 – Residential Clothes Washer

COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%.[138]

[136] 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).
[137] 2018 GTI Residential Ozone Laundry Field Demonstration (May 2018).
[138] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

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

%ElectricDHW = Proportion of water heating supplied by electric heating

DHW fuel	%FossilDHW
Electric	100%
Natural gas	0%
Unknown	16%[139]

Capacity = Clothes washer capacity (cubic feet).

= Actual. If unknown, assume 5.0 cubic feet.[140]

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

= Actual. If unknown, use the following values

Efficiency Level	IWF (gallons/cycle/ft3)	
	Top loading > 2.5 Cu ft	Front Loading > 2.5 Cu ft
Federal Standard (up to January 1, 2018)	8.4	4.7
Federal Standard (after January 1, 2018) – Use if unit level is unknown.	6.5	4.7
ENERGY STAR (as of February 2018)	4.3	3.2
CEE Tier 2	3.2	3.2

%HotWater = Percentage of water usage that is supplied by the domestic hot water heater when the hot or warm wash cycles are selected.[141]

Single-Family Home	Multifamily
0.1759	0.2960

T_{OUT} = Tank temperature

139 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.

140 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_2019.xlsx' and 'Multifamily Ozone Summary Calcs_2019.xlsx' 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.

141 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_2019.xlsx' and 'Multifamily Ozone Summary Calcs_2019.xlsx' for more information.

= 125°F

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

= 50.7°F [142]

8.33 = Specific weight of water (lbs/gallon)

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

Ncycles = Number of Cycles per year

Single-Family Home	Multifamily
295[143]	1,243[144]

RE_electric = Recovery efficiency of electric water heater

= 98% [145]

3412 = Btus to kWh conversion (Btu/kWh)

$\%HotWash_{base}$ = Average percentage of loads that use hot or warm water with baseline equipment. [146]

Single-Family Home	Multifamily
0.7743	0.7438

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

= 0.0

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

ΔkWh = (1 * 5.0 * 6.5 * 0.1759 * (125 – 50.7) * 8.33 * 1.0 * 295) / (0.98 * 3412) * (0.7743 – 0)

= 242 kWh

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Assumed Run hours of Clothes Washer

[142] Table 4 in Chen, et. al., "Calculating Average Hot Water Mixes of Residential Plumbing Fixtures", June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.

[143] Weighted average of clothes washer cycles per year (based on 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, state of Illinois.
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.

[144] DOE Technical Support Document Chapter 6, 2010 https://www.regulations.gov/contentStreamer?documentId=EERE-2006-STD-0127-0118&attachmentNumber=8&disposition=attachment&contentType=pdf

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

[146] GTI Residential Ozone Laundry Field Demonstration (May 2018). See 'Residential Ozone Summary Calcs_2019.xlsx' and 'Multifamily Ozone Summary Calcs_2019.xlsx' for more information.

= 264 hours[147]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[148]

> **For example**, a residential ozone laundry system is installed in a single-family home with an electric domestic hot water heater. The capacity and IWF of the baseline equipment is unknown.
>
> ΔkW = 231/295 * 0.038
>
> = 0.0298kW

NATURAL GAS SAVINGS

ΔTherm = ThermHotWash * (%HotWash$_{base}$ - %HotWash$_{Ozone}$)

Where:

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

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

DHW fuel	%FossilDHW
Electric	0%
Natural gas	100%
Unknown	84%[149]

RE_gas = Recovery efficiency of gas water heater

Single-Family Homes	Multifamily
78%[150]	67%[151]

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

> **For example**, a residential ozone laundry system is installed in a single-family home with a gas domestic hot water heater. The capacity and IWF of the baseline equipment is unknown.
>
> ΔTherms = (1 * 5.0 * 6.5 * 0.1759 * (125 – 50.7) * 8.33 * 1.0 * 295) / (0.78 * 100,000) * (0.7743 – 0)
>
> = 10.4 Therms

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

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

149 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.

150 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%.

151 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 IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

LAUNDRY DETERGENT SAVINGS

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

Detergent savings per year = Detergent_cost * Ncycles

Where:

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

= 0.16[152]

> **For example**, a residential ozone laundry system is installed in a single-family home.
>
> Detergent savings per year = 0.16 * 295
>
> = $47.20

MEASURE CODE: RS-APL-OZNE-V04-220101

REVIEW DEADLINE: 1/1/2023

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

5.1.13 Income Qualified: ENERGY STAR and CEE Tier 2 Room Air Conditioner

DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets ENERGY STAR version 4.0 which is effective October 26th 2015 (equivalent to CEE Tier 1) or CEE Tier 2 minimum qualifying efficiency specifications, in place of an existing inefficient unit or a newly acquired inefficient unit through the secondary market. This measure is to be used by programs supporting the installation of efficient Room AC in income qualified households. The COVID pandemic of 2020 has meant that opportunities for income qualified populations to keep themselves and their families cool and comfortable during the summer heat have been restricted as access to cooling centers and air conditioned public areas have become limited. This can result in hospitalization or even death from heat exhaustion.

It is assumed that the Room AC's characterized in this measure are being used less as a luxury and more as a necessity and that access to a single AC unit per household will result in run hours more consistent with central AC usage.

This measure was developed to be applicable to the following program types: TOS, 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)[153] efficiency standards presented above.

Product Type and Class (Btu/hr)		ENERGY STAR v4.0 with louvered sides (CEER)	ENERGY STAR v4.0 without louvered sides (CEER)	CEE Tier 2 (CEER)[154]
Without Reverse Cycle	< 8,000	12.1	11.0	12.7
	8,000 to 10,999	12.0	10.6	12.5
	11,000 to 13,999	12.0	10.5	12.5
	14,000 to 19,999	11.8	10.2	12.3
	20,000 to 27,999	10.3	10.3	10.8
	>=28,000	9.9	10.3	10.4
With Reverse Cycle	<14,000	10.8	10.2	12.5
	14,000 to 19,999	10.8	9.6	12.3
	>=20,000	10.2	9.6	10.4
Casement only		10.5		
Casement-Slider		11.4		

DEFINITION OF BASELINE EQUIPMENT

For both Time of Sale and Early Replacement the baseline assumption is an inefficient unit either existing in the home or being purchased or acquired via the secondary market.

153 ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements

154 The Consortium for Energy Efficiency Super Efficient Home Appliance Initiative, Room Air Conditioner Specification, CEE Advanced Tier (CEER), effective January 31, 2017. Please see file "CEE_ResApp_RoomAirConditionerSpecification_2017.pdf". https://library.cee1.org/system/files/library/13069/CEE_ResApp_RoomAirConditionerSpecification_2017.pdf

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years.[155]

It is assumed that the baseline unit would need to be replaced with an additional secondary unit after 6 years.

DEEMED MEASURE COST

The actual full cost of the ENERGY STAR unit should be used. If unavailable assume $300.[156] If a CEE Tier 2 unit is installed assume $508.[157]

The cost of the inefficient secondary market unit is assumed to be $50.

Therefore, where the new unit replaces an existing unit the measure cost is $300 for ENERGY STAR or $508 for CEE Tier 2, and where there is no existing unit the measure cost is assumed to be $250 for ENERGY STAR or $458 for CEE Tier 2.

The avoided replacement cost (after 6 years) of the replacement secondary market unit is $50. This cost should be discounted to present value using the nominal societal discount rate.

LOADSHAPE

Loadshape R08 - Residential Cooling

COINCIDENCE FACTOR

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

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 68%[158]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 46.6%[159]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (FLH_{RoomAC} * Btu/H * (1/(EERbase/1.01) - 1/CEERee))/1000$$

Where:

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

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

156 To promote improved cost effectiveness, it is assumed that the lower cost ENERGY STAR Room AC units would be used. Units between $200-$400 are available dependent on capacity.

157 Consistent with Non IQ version of the measure.

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

159 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.

= dependent on location:

Climate Zone (City based upon)	FLHcool (single family)	FLHcool (multifamily)	FLH_cooling (weatherized multifamily)[160]
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[161]	629	564	362

Btu/H = Size of installed unit

= Actual. If unknown assume 8500 Btu/hr[162]

EERbase =Efficiency of existing / baseline unit

= Actual. If unknown assume 7.7 [163]

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption)[164]

CEERee = Combined Energy Efficiency Ratio of ENERGY STAR unit

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

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

$\Delta kWH_{ENERGY\ STAR}$ = (564 * 8500 * (1/(7.7/1.01) – 1/12.0)) / 1000

= 229 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

= 68%[165]

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

[160] *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.
[161] Weighted based on number of residential occupied housing units in each zone.
[162] Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008
[163] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."
[164] 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'.
[165] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 46.6%[166]

1.02 = Factor to convert CEER to EER (CEER includes standby and off power consumption)[167]

Other variable as defined above

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

ΔkW_{SSP} = (8500 * (1/7.7– 1/(12.0*1.01))) / 1000 * 0.68

= 0.2738 kW

ΔkW_{PJM} = (8500 * (1/7.7– 1/(12.0*1.01))) / 1000 * 0.466

= 0.1876 kW

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-IQRA-V02-220101

REVIEW DEADLINE: 1/1/2024

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

167 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’.

5.2 Consumer Electronics End Use

5.2.1 Advanced Power Strip – Tier 1

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the advanced power strip is 7 years.[168]

DEEMED MEASURE COST

For time of sale or new construction the incremental cost of an advanced Tier 1 power strip over a standard power strip with surge protection is assumed to be $10.[169]

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

LOADSHAPE

Loadshape R13 - Residential Standby Losses – Entertainment

Loadshape R14 - Residential Standby Losses - Home Office

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 80%.[170]

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

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

[170] Efficiency Vermont 2016 TRM coincidence factor for advanced power strip measure –in the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = kWh * ISR

Where:

kWh = Assumed annual kWh savings per unit

= 56.5 kWh for 5-plug units or 103 kWh for 7-plug units[171]

ISR = In Service Rate, dependent on delivery mechanism

Delivery Mechanism	ISR
Multifamily Energy Efficiency Kit, Leave behind	40%[172]
Single Family Energy Efficiency Kit, Leave behind	55%[173]
Community Distributed Kit	91%[174]
Direct Install	100%
Time of Sale	71%[175]

Using assumptions above:

# Plugs	Delivery Mechanism	ΔkWh
5- plug	Multifamily Energy Efficiency Kit, Leave behind	22.6
	Single family Energy Efficiency Kit, Leave behind	31.1
	Community Distributed Kit	51.4
	Direct Install	56.5
	Time of Sale	40.1
7-plug	Multifamily Energy Efficiency Kit, Leave behind	41.2

171 NYSERDA Measure Characterization for Advanced Power Strips. Study based on review of:
Smart Strip Electrical Savings and Usability, Power Smart Engineering, October 27, 2008.
Final Field Research Report, Ecos Consulting, October 31, 2006. Prepared for California Energy Commission's PIER Program.
Developing and Testing Low Power Mode Measurement Methods, Lawrence Berkeley National Laboratory (LBNL), September 2004. Prepared for California Energy Commission's Public Interest Energy Research (PIER) Program.
2005 Intrusive Residential Standby Survey Report, Energy Efficient Strategies, March 2006.
Smart Strip Portfolio of the Future, Navigant Consulting for San Diego G&E, March 31, 2009.
"Smart strip" in this context refers to the category of Advanced Power Strips, does not specifically signify Smart Strip® from BITS Limited, and was used without permission. Smart Strip® is a registered trademark of BITS Smart Strip, LLC.

172 Opinion Dynamics and Navigant. Impact Evaluation for ComEd 2018 site visit efforts for leave-behind measures in public housing multi-family units. The Evaluation Team completed site visits for 72 apartment units across seven of the ten participating properties in which advanced power strips were installed. The Evaluation Team attempted a census using all data provided at the time of site visit planning (Fall 2018). The program distributed a total of 476 advanced power strips, with 471 distributed amongst the seven properties with completed site visits. The Team performed intrasite sampling within each property and verified a total of 37 advanced power strips of the 92 within the sample.

173 Research from 2018 ComEd Home Energy Assessment participant survey.

174 Research from 2018 Ameren Illinois Income Qualified participant survey.

175 Research from 2019 ComEd Appliance Rebate Program- Online Marketplace participant survey

# Plugs	Delivery Mechanism	ΔkWh
	Single family Energy Efficiency Kit, Leave behind	56.7
	Community Distributed Kit	93.8
	Direct Install	103.0
	Time of Sale	73.1
Unknown[176]	Multifamily Energy Efficiency Kit, Leave behind	31.9
	Single family Energy Efficiency Kit, Leave behind	43.9
	Community Distributed Kit	72.6
	Direct Install	80.0
	Time of Sale	56.6

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / Hours * CF

Where:

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

= 7,129 [177]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [178]

# Plugs	Delivery Mechanism	ΔkW
5- plug	Multifamily Energy Efficiency Kit, Leave behind	0.0025
	Single family Energy Efficiency Kit, Leave behind	0.0035
	Community Distributed Kit	0.0058
	Direct Install	0.0063
	Time of Sale	0.0045
7-plug	Multifamily Energy Efficiency Kit, Leave behind	0.0046
	Single family Energy Efficiency Kit, Leave behind	0.0064
	Community Distributed Kit	0.0105
	Direct Install	0.0116
	Time of Sale	0.0082
Unknown[179]	Multifamily Energy Efficiency Kit, Leave behind	0.0036
	Single family Energy Efficiency Kit, Leave behind	0.0049

[176] Calculated as average of 5 and 7 plug savings assumptions.
[177] Average of hours for controlled TV and computer from; NYSERDA Measure Characterization for Advanced Power Strips
[178] 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.
[179] Calculated as average of 5 and 7 plug savings assumptions.

# Plugs	Delivery Mechanism	ΔkW
	Community Distributed Kit	0.0081
	Direct Install	0.0090
	Time of Sale	0.0064

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-CEL-SSTR-V07-210101

REVIEW DEADLINE: 1/1/2024

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

DESCRIPTION

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

By utilizing advanced control strategies such as a countdown timer, external sensors (e.g. of infra-red remote usage and/or occupancy sensors, true RMS (Root Mean Square) power sensing; both active power loads and standby power loads of controlled devices are managed by Tier 2 AV APS devices.[180] 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'.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is the use of a Tier 2 AV APS in a residential AV (home entertainment) environment that includes control of at least 2 AV devices with one being the television.[181]

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.

[180] 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.

[181] 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.

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The default deemed lifetime value for Tier 2 AV APS is assumed to be 7 years.[182]

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%.[183]

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[182] 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.

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

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

ERP = Energy Reduction Percentage of qualifying Tier2 AV APS product range as provided below. Savings are based upon independent field trials of two product manufacturers and the savings differences are assumed to relate to the product classifications provided below. Additional evaluation will be reviewed in future cycles to confirm if additional classification categories are appropriate.

Product Type	ERP used
Infrared Only	40%[184]
Infrared and Occupancy Sensor	25%[185]

$BaselineEnergy_{AV}$ = 466 kWh[186]

ISR = In Service Rate.

Product Type	ISR[187]
Infrared Only	73%
Infrared and Occupancy Sensor	83%

Deemed savings for each product type are provided below:

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[184] Representative savings assumption based on the following independent field tests on Embertec's IR-only product. This includes both simulated saving results (based on recording what action the APS would have taken, but where equipment is not actually switched off allowing evaluation of the expected length of savings), and pre/post metering studies.

- AESC (page 30) - Valmiki, MM., Corradini, Antonio PE. 2015. *Tier 2 Advanced Power Strips in Residential and Commercial Applications*. Prepared for San Diego Gas & Electric by Alternative Energy Systems Consulting, Inc. (Simulated 50%, pre/post 32%).
- AESC- Valmiki, MM., Corradini, Antonio PE., Feb 2016. *Energy Savings of Tier 2 Advanced Power Strips in Residential AV Systems.* (Simulated 50%, pre/post 29%)
- CalPlug research (Page 12) - Wang, M. e. 2014. "*Tier 2 Advanced Power Strip Evaluation for Energy Saving Incentive".* California Plug Load Research Center (CalPlug), UC Irvine. (Simulated 51%)
- NMR Group Inc., *RLPNC 17-3: Advanced Power Strip Metering Study*, Revised March 18, 2019, submitted to Massachusetts Program Administrators and EEAC. (Pre/post with regression 50%, Pre/post only 20%).

[185] Representative savings assumption based on the following independent field tests on TrickeStar IR-OS product and reflect both simulated and pre/post meter study results.

- AESC- Valmiki, MM., Corradini, Antonio PE., Feb 2016. *Energy Savings of Tier 2 Advanced Power Strips in Residential AV Systems.* (Simulated 27%, pre/post 25%)
- NMR Group Inc., *RLPNC 17-3: Advanced Power Strip Metering Study*, Revised March 18, 2019, submitted to Massachusetts Program Administrators and EEAC. (Pre/post with regression 37%, Pre/post only 11%)

[186] Average of baseline energy in Regional Technical Form survey of Tier 2 APS pre-post methodology studies, see 'RTF_T2_APS.ppt'.

[187] Weighted average of evaluation results from AESC, Inc, "Energy Savings of Tier 2 Advanced Power Strips in Residential AC Systems", p35. These assumptions include "adjustments in weighting based on the persistence sensitivity to demographics" and NMR Group Inc., RLPNC 17-3: Advanced Power Strip Metering Study, Revised March 18, 2019.

Product Type	ΔkWh
Infrared Only	136.1
Infrared and Occupancy Sensor	96.7

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / Hours * CF

Where:

ΔkWh = Energy savings as calculated above

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

= 4,380 [188]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [189]

Deemed savings for each product type are provided below:

Product Type	ΔkW
Infrared Only	0.0249
Infrared and Occupancy Sensor	0.0177

NATURAL GAS SAVINGS

N/A[190]

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-CEL-APS2-V05-210101

REVIEW DEADLINE: 1/1/2024

[188] 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.
[189] 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.
[190] 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 relates to a unitary central heat pump (split or packaged) with conditioned air delivered to the home via ductwork.

This measure characterizes:

a) New Construction:

- The installation of a new residential sized (<= 65,000 Btu/hr) Air Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new home.
- 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:

- The installation of a new residential sized (<= 65,000 Btu/hr) Air Source Heat Pump that is more efficient than required by federal standards. This relates to the replacement of an existing unit at the end of its useful life.
- Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. Where unknown, the baseline should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.
- 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:

The early removal of functioning electric or gas heating and/or 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.

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.

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).[191]
- 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

[191] 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.

replacement rates are unknown.

Deemed Early Replacement Rates For ASHP

	Deemed Early Replacement Rate
Early Replacement Rate for ASHP participants	36%[192]

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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 EER.[193]

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, 10.5 EER.[194]

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 EER, 8.2 HSPF
Gas Furnace	80% AFUE
Gas Boiler	84% AFUE
Central AC	13 SEER, 10.5 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).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years.[195]

Remaining life of existing equipment is assumed to be 6 years for ASHP and Central AC, 7 years for furnace, 8 years

[192] Based on ComEd program data from 2018-2020 (444 ASHP installs).
[193] 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'.
[194] 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'.
[195] Based on 2016 DOE Rulemaking Technical Support document, as recommended in Guidehouse 'ComEd Effective Useful Life Research Report', May 2018.

for boilers[196] and 16 years for electric resistance.[197]

DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the Air Source Heat Pump (including any necessary electrical or distribution upgrades required) should be used minus the assumed installation cost of the baseline equipment ($1,381 per ton for a new baseline ASHP, $2,011 for a new baseline 80% AFUE furnace or $4,053 for a new 84% AFUE boiler[198] and $952 per ton for new baseline Central AC replacement[199]).

Early Replacement: The actual full installation cost of the Air Source Heat Pump (including any necessary electrical or distribution upgrades required) should be used. The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,584 per ton for a new baseline Air Source Heat Pump, or $2,296 for a new baseline 80% AFUE furnace or $4,627 for a new 84% AFUE boiler and $1,092 per ton for new baseline Central AC replacement.[200] This future cost should be discounted to present value using the nominal societal discount rate.

If the install cost of the efficient Air Source Heat Pump is unknown, assume the following (note these costs are per ton of unit capacity);[201] however, because these assumptions do not include any additional costs that may be required for fuel switch scenarios, these defaults should not be used and actual costs should always be used for fuel switch measures:

Efficiency (SEER)	Full Efficient ASHP 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

Quality Installation: The additional design and installation work associated with quality installation has been estimated to cost an additional $150.[202]

LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

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

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

196 Assumed to be one third of effective useful life of replaced equipment.

197 Assume full measure life (16 years) for replacing electric resistance as we would not expect that resistance heat would fail during the lifetime of the efficient measure.

198 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.

199 Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator.

200 All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.98%.

201 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 "HVAC Program: Incremental Cost Analysis Update", December 19, 2016 study results.

202 Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers in Iowa.

utility peak hour)

= 72%[203]

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

= 46.6%[204]

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

= 67%[205]

$CF_{PJM,\ MF}$ = 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 AND NATURAL GAS SAVINGS

Non fuel switch measures:

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

Fuel switch measures:

Fuel switch measures must produce positive total lifecycle fuel savings (i.e., reduction in Btus at the premises) in order to qualify. This is determined as follows (note for early replacement measures the lifetime savings should be calculated by calculating savings for the remaining useful life of the existing equipment and for the remaining measure life):

SiteEnergySavings (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – ASHPSiteHeatConsumed + ASHPSiteCoolingImpact

GasHeatReplaced = (HeatLoad * 1/$AFUE_{base}$) / 1,000,000

FurnaceFanSavings = (FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e) / 1,000,000

ASHPSiteHeatConsumed = ((HeatLoad * (1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) /1000 * 3412)/ 1,000,000

ASHPSiteCoolingImpact = ((FLHcool * Capacity_ASHPcool * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) -

[203] 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)'.

[204] 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.

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

1/(SEER_ee * SEERadj * (1 – DeratingCool$_{Eff}$))))/1000 * 3412) / 1,000,000

If SiteEnergySavings calculated above is positive, the measure is eligible.

The appropriate savings claim is dependent on which utilities are supporting the measure as provided in a table below:

Measure supported by:	Electric Utility claims (kWh):	Gas Utility claims (therms):
Electric utility only	SiteEnergySavings * 1,000,000/3,412	N/A
Electric and gas utility (Note utilities may make alternative agreements to how savings are allocated as long as total MMBtu savings remains the same).	%IncentiveElectric * SiteEnergySavings * 1,000,000/3,412	%IncentiveGas * SiteEnergySavings * 10
Gas utility only	N/A	SiteEnergySavings * 10

Note for Early Replacement measures, the efficiency and Fe terms of the existing unit should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC, 6 years for furnace, 8 years for boilers, 15 years for electric resistance), and the efficiency and Fe terms for a new baseline unit should be used for the remaining years of the measure. See assumptions below.

Where:

FLH_cooling = Full load hours of air conditioning

= dependent on location:

Climate Zone (City based upon)	FLH_cooling (single family) [206]	FLH_cooling (general multifamily) [207]	FLH_cooling (weatherized multifamily) [208]
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[209]	629	564	362

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

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

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

[206] 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.

[207] Ibid.

[208] *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.

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

SEER_base = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh). For early replacment measures, the actual SEER rating where it is possible to measure or reasonably estimate should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[210] or if unknown assume default provided below:

Baseline/Existing Cooling System	SEER_base		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	9.3[211]	14[212]	
Central AC	9.3[213]	13[214]	
No central cooling	Make '1/SEER_exist' = 0 [215]	13[216]	

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

= Actual, or 15 if unknown.[217]

SEERadj = Adjustment percentage to account for in-situ performance of the unit[218]

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

$DeratingCool_{Eff}$ = Efficent ASHP Cooling derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown[219]

$DeratingCool_{Base}$ = Baseline Cooling derating

= 10%

HeatLoad = Calculated heat load for the building (Btus)

= FLH_ASHPheat * Capacity_ASHPheat

FLH_ASHPheat = Full load hours of heat pump heating

[210] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).
[211] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[212] Minimum Federal Standard as of 1/1/2015
[213] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[214] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
[215] 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.
[216] Assumes that the decision to replace existing systems includes desire to add cooling.
[217] ENERGY STAR minimum.
[218] 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'.
[219] 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') and so could be considered for future evaluation.

= Dependent on location and home type:

Climate Zone (City based upon)	FLH_heat (single family and general multifamily)[220]	FLH heat (weatherized multifamily) [221]
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[222]	1,821	692

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

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

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

HSPF_base = Heating System Performance Factor of baseline heating system (kBtu/kWh). For early replacement measures, use actual HSPF rating where it is possible to measure or reasonably estimate for the remaining useful life of the existing equipment (6 years for ASHP, 16 years for electric resistance). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[223] or if unknown assume default:

Baseline/ Existing Heating System	HSPF_base		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	5.54[224]	8.2[225]	
Electric Resistance	3.41[226]		

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

(kBtu/kWh)

= Actual or 8.5 if unknown[227]

[220] 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.

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

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

[223] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

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

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

[227] ENERGY STAR minimum.

HSPFadj = Adjustment percentage to account for the heating capacity ratio of the efficient unit[228]

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

= Actual using AHRI lookup values for efficient unit heating capacities rated at 17°F and 47°F. If not available assume 1.[229]

$DeratingHeat_{Eff}$ = Efficent ASHP Heating derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed[230]

$DeratingHeat_{Base}$ = Baseline Heatin derating

= 10%

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating. For early replacement measures, use actual AFUE rating where it is possible to measure or reasonably estimate for the remaining useful life of the existing equipment (6 years for furnace, 8 years for boilers). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[231] or if unknown assume default:

Baseline/ Existing Heating System	AFUEbase		
	Early Replacement (Remaining useful life of existing equipment)[232]	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Furnace	64.4%	80%	80%
Boiler	61.6%	84%	84%

FurnaceFlag = 1 if system replaced is a gas furnace, 0 if not.

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

For Early Replacement (1st 6 years) F_e_Exist = 3.14%[233]

For New Construction, Time of Sale and early replacement (remaining 10 years) F_e_New = 1.88%[234]

3412 = Btu per kWh

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[228] 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'.

[229] In situ performance based on Guidehouse review of 201 ASHP installs. While the data indicated an average of 1.006, the range was 0.9 to 1.06 so calculation of this value should be done where possible.

[230] 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') and so could be considered for future evaluation.

[231] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

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

[234] New furnaces are required to have ECM fan motors installed. Comparing Eae to Ef for furnaces on the AHRI directory as above, indicates that Fe for new furnaces is on average 1.88%.

%IncentiveElectric = % of total incentive paid by electric utility

= Actual

%IncentiveGas = % of total incentive paid by gas utility

= Actual

Non Fuel Switch Illustrative Examples

Time of Sale using ASHP baseline:

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

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

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

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

= 1463 kWh

Early Replacement:

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

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

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

= 5489 kWh

ΔkWH for remaining measure life (next 12 years):

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

= 1463 kWh

Fuel Switch Illustrative Examples

[for illustrative purposes, 50:50 Incentive is used for joint programs]

New construction using gas furnace and central AC baseline:

For example a three ton (Cooling capacity of 34,800Btuh and Heating capacity of 33,000 Btuh), 15 SEER, 12EER, 9 HSPF Air Source Heat Pump installed in single-family home in Marion with Quality Installation, in place of a 81,000 Btuh natural gas furnace and 3 ton Central AC unit:

SiteEnergySavings (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – ASHPSiteHeatConsumed + ASHPSiteCoolingImpact

GasHeatReplaced = ((HeatLoad * 1/$AFUE_{base}$) / 1,000,000)

= ((1288 * 33,000 * 1/0.8) / 1000000)

= 53.1 MMBtu

FurnaceFanSavings = (FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e_New) / 1,000,000

= (1 * 1288 * 33,000 * 1/0.8 * 0.0188) / 1,000,000

= 1.0 MMBtu

ASHPSiteHeatConsumed = ((HeatLoad * (1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) /1000 * 3412)/ 1,000,000

= ((1,288 * 33,000 * (1/(9 * 1.001 * (1-0)))) / 1000 * 3412)/ 1,000,000

= 16.1 MMBtu

Fuel Switch Illustrative Example continued

ASHPSiteCoolingImpact = ((FLH_cool * Capacity_cooling * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$))))/1000) * 3412) / 1,000,000

= ((903 * 34,800 * (1/(13 * (1-0.1)) - 1/(15 * 1.011 * (1-0)))) / 1000 * 3412)/1,000,000

= 2.1 MMBtu

SiteEnergySavings (MMBTUs) = 53.1 + 1.0 – 16.1 + 2.1 = 40.1 MMBtu [Measure is eligible]

Savings would be claimed as follows:

Measure supported by:	Electric Utility claims:	Gas Utility claims:
Electric utility only	40.1 * 1,000,000/3412 = 11,752 kWh	N/A
Electric and gas utility	0.5 * 40.1 * 1,000,000/3412 = 5,876 kWh	0.5 * 40.1 * 10 = 401 Therms
Gas utility only	N/A	40.1 * 10 = 200.5 Therms

Early Replacement fuel switch:

For example a three ton (Cooling capacity of 34,800Btuh and Heating capacity of 33,000 Btuh), 15 SEER, 12EER, 9 HSPF Air Source Heat Pump installed in single-family home in Marion with Quality Installation, replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings:

LifetimeSiteEnergySavings (MMBTUs) = LifetimeGasHeatReplaced + LifetimeFurnaceFanSavings – LifetimeASHPSiteHeatConsumed + LifetimeASHPSiteCoolingImpact

LifetimeGasHeatReplaced = [(HeatLoad * 1/$AFUE_{exist}$) / 1,000,000] * 6 years + [(HeatLoad * 1/$AFUE_{base}$) / 1,000,000] * 10 years

= (((1288 * 33000 * 1/0.644) / 1000000) * 6) + (((1288 * 33000 * 1/0.8) / 1000000) * 10)

=927.3 MMBtu

LifetimeFurnaceFanSavings = ((FurnaceFlag * HeatLoad * 1/$AFUE_{exist}$ * F_e_Exist) / 1,000,000) * 6 years + ((FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e_New) / 1,000,000) * 10 years

= ((1 * 1288 * 33,000 * 1/0.644 * 0.0314) / 1,000,000) * 6 + ((1 * 1288 * 33,000 * 1/0.8 * 0.0188)/ 1,000,000) * 10

= 22.4 MMBtu

LifetimeASHPSiteHeatConsumed = ((HeatLoad * (1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) /1000 * 3412)/ 1,000,000 * 16 years

= ((1,288 * 33,000 * (1/(9 * 1.001 * (1-0)))) / 1000 * 3412)/1,000,000 * 16

= 257.6 MMBtu

Fuel Switch Illustrative Example continued

LifetimeASHPSiteCoolingImpact = (((FLHcool * Capacity_cooling * (1/(SEER_exist * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$))))/1000 * 3412)/1,000,000 * 6 years) + (((FLHcool * Capacity_cooling * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$))))/1000 * 3412)/1,000,000 * 10 years)

= (((903 * 34,800 * (1/(9.3 * (1-0.1)) - 1/(15 * 1.011 * (1-0)))) / 1000 * 3412)/1,000,000 * 6) + (((903 * 34,800 * (1/(13 * (1-0.1)) - 1/(15 * 1.011 * (1-0)))) / 1000 * 3412)/1,000,000 * 10)

= 55.4 MMBtu

LifetimeSiteEnergySavings (MMBTUs) = 927.3 + 22.4 – 257.6 + 55.4 = 747.5 MMBtu [Measure is eligible]

First 6 years:

SiteEnergySavings_FirstYear (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – ASHPSiteHeatConsumed + ASHPSiteCoolingImpact

GasHeatReplaced = [(HeatLoad * 1/$AFUE_{Exist}$) / 1,000,000]

= ((1288 * 33,000 * 1/0.644) / 1000000)

= 66.0 MMBtu

FurnaceFanSavings = (FurnaceFlag * HeatLoad * 1/$AFUE_{Exist}$ * F_e_Exist) / 1,000,000

= (1 * 1288 * 33,000 * 1/0.644 * 0.0314) / 1,000,000

= 2.1 MMBtu

ASHPSiteHeatConsumed = ((HeatLoad * (1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) /1000 * 3412)/ 1,000,000

= ((1,288 * 33,000 * (1/(9 * 1.001 * (1-0)))) / 1000 * 3412) / 1,000,000

= 16.1 MMBtu

ASHPSiteCoolingImpact = ((FLH_cool * Capacity_cooling * (1/(SEER_exist * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$))))/1000 * ($FirstYearH_{grid}$ * (1 + ElectricT&D)) / 1,000,000

= ((903 * 34,800 * (1/(9.3 * (1-0.1)) - 1/(15 * 1.011 * (1-0)))) / 1000 * 3412)/1,000,000

= 5.7 MMBtu

SiteEnergySavings_FirstYear (MMBTUs) = 66.0 + 2.1 – 16.1 + 5.7 = 57.7 MMBtu

Remaining 10 years:

SiteEnergySavings_PostAdj (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – ASHPSiteHeatConsumed + ASHPSiteCoolingImpact

GasHeatReplaced = ((1288 * 33,000 * 1/0.8) / 1000000)

= 53.1 MMBtu

FurnaceFanSavings = (FurnaceFlag * HeatLoad * 1/$AFUE_{Base}$ * F_e_New) / 1,000,000

= (1 * 1288 * 33,000 * 1/0.8 * 0.0188) / 1,000,000

= 1.2 MMBtu

Fuel Switch Illustrative Example continued

ASHPSiteHeatConsumed = ((1,288 * 33,000 * (1/(9 * 1.001 * (1-0)))) / 1000 * 3412) / 1,000,000

= 16.1 MMBtu

ASHPSiteCoolingImpact = ((903 * 34,800 * (1/(13 * (1-0.1)) - 1/(15 * 1.011 * (1-0)))) / 1000 *3412)/1,000,000

= 2.1 MMBtu

SiteEnergySavings_ PostAdj (MMBTUs) = 53.1 + 1.2 – 16.1 + 2.1 = 40.3 MMBtu

Savings would be claimed as follows:

Measure supported by:	Electric Utility claims:	Gas Utility claims:
Electric utility only	First 6 years: 57.7 * 1,000,000/3412 = 16,911 kWh Remaining 10 years: 40.3 * 1,000,000/3412 = 11,811 kWh	N/A
Electric and gas utility	First 6 years: 0.5 * 57.7 * 1,000,000/3412 = 8,455 kWh Remaining 10 years: 0.5 * 40.3 * 1,000,000/3412 = 5,906 kWh	First 6 years: 0.5 * 57.7 * 10 = 288.5 Therms Remaining 10 years: 0.5 * 40.3 * 10 = 201.5 Therms
Gas utility only	N/A	First 6 years: 57.7 * 10 = 577 Therms Remaining 10 years: 40.3 * 10 = 403 Therms

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

EER_base = Energy Efficiency Ratio of baseline unit (kBtu/kWh). For early replacment measures, the actual EER rating where it is possible to measure or reasonably estimate should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.[235] If unknown, assume default provided below:

[235] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

Baseline/Existing Cooling System	EER_base		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	7.5[236]	11.0[237]	
Central AC	7.5[238]	10.5[239]	
No central cooling	Make '1/EER_exist' = 0 [240]	10.5[241]	

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

= Actual. If unknown, assume 12.5 EER.[242]

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

= 72%[243]

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

= 46.6%[244]

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

= 67%[245]

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

= 28.5%

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

236 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
237 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'.
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 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'.
240 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.
241 Assumes that the decision to replace existing systems includes desire to add cooling.
242 ENERGY STAR minimum.
243 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)'.
244 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.
245 *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:

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

= 0.458 kW

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

= 0.297 kW

Early Replacement:

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

ΔkW_{SSP} for remaining life of existing unit (1st 6 years):

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

= 1.68 kW

ΔkW_{SSP} for remaining measure life (next 10 years):

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

= 0.458 kW

ΔkW_{PJM} for remaining life of existing unit (1st 6 years):

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

= 1.087 kW

ΔkW_{PJM} for remaining measure life (next 10 years):

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

= 0.297 kW

NATURAL GAS SAVINGS

Calculation provided together with Electric Energy Savings 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 ASHP 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. For Early Replacement measures, the efficiency and Fe terms of the existing unit should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC, 6 years for furnace, 8 years for boilers or GSHP, 15 years for electric resistance), and the efficiency and Fe terms for a new baseline unit should be used for the remaining years of the measure.

ΔTherms = [Heating Consumption Replaced]

= [(HeatLoad * 1/$AFUE_{base}$) / 100,000]

ΔkWh = [FurnaceFanSavings] - [ASHP heating consumption] + [Cooling savings]

= [FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e * 0.000293] - [(HeatLoad * (1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$))))/1000] + [(FLHcool * Capacity_ASHPcool * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$))))/1000]

MEASURE CODE: RS-HVC-ASHP-V11-220101

REVIEW DEADLINE: 1/1/2025

5.3.2 Boiler Pipe Insulation

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline is an un-insulated boiler pipe.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.[246]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 13 years.[247] See section below for detail.

DEEMED MEASURE COST

The actual installation cost should be used if known. If unknown, the measure cost including material and installation is assumed to be $3 per linear foot.[248] For foam pipe insulation assume a measure cost of $0.26/ft for ½" insulation and $0.31/ft for ¾" insulation.[249]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

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[246] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[247] 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.
[248] Consistent with DEER 2008 Database Technology and Measure Cost Data.
[249] Review of website cost data for Homedepot.com, Lowes.com, and Menards.com for locations in Peoria, IL.

NATURAL GAS SAVINGS

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

Where:

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

= Varies based on pipe size and material. See table below for values.

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

= Actual (R_{exist} + R value of insulation[250])

C_{inside} = Inside circumference of the pipe [ft]

= Actual (0.5" pipe = 0.1427 ft, 0.75" pipe = 0.2055 ft); See table below for values.

$L_{effective}$ = Effective Length of pipe from boiler covered by pipe insulation (ft)[251]

= $L_{Horizontal} + \alpha L_{Vertical}$

= Actual; See table below for α values. If unknown, assume 3ft of vertical and remaining horizontal.

FLH_heat = Full load hours of heating

= Dependent on location:[252]

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[253]	1,821

ΔT = Average temperature difference between circulated heated water and unconditioned space air temperature (°F) [254]

[250] Where possible it should be ensured that the R-value of the insulation is at the appropriate mean rating temperature (125F).
[251] In cases with zero wind, heat loss (and therefore) savings is larger from horiztonal pipe configurations than vertical pipe configurations due, perhaps to the way in which convective losses are handled. An analysis of the 3E PLUS tool by NAIMA (https://insulationinstitute.org/tools-resources/free-3e-plus/) yielded adjustment factors for horizontal to vertical loss and savings values. See DHW_PipeInsulationCalcs_062121.xlsx for details of the analysis and comparisons.
[252] Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the ENERGY STAR Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider ENERGY STAR estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from Illinois Commerce Commission) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the ENERGY STAR data (1994 hours) to scale down the ENERGY STARr estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
[253] Weighted based on number of occupied residential housing units in each zone.
[254] 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 unconditioned basement:

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

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[255]	125	85

ηBoiler = Efficiency of boiler

= 0.819 [256]

Parameter assumptions for various pipe sizes and materials:

Type and Size	C_{Inside}[257] (I.D.*π/12) (ft)	Product of Overall Heat Transfer Coefficient and Pipe Area (UA) per foot[258] from bare pipe (BTU/hr·ft·°F)	Pipe Area per linear foot (ft^3)[259]	R_{exist} ((hr·ft·°F)/BTU)	Horizontal to Vertical Adjustment Factor (α)
½" Copper Pipe	0.1427	0.345	0.153	0.444	0.67
¾" Copper Pipe	0.2055	0.417	0.217	0.521	0.72
½" PEX	0.1270	0.438	0.145	0.332	0.73
¾" PEX	0.1783	0.545	0.204	0.374	0.77

For example, insulating 10 feet of 0.75" copper pipe (4ft vertical and 6 ft horizontal) with R-3 insulation in a crawl space of a Marion home with a boiler without reset control:

ΔTherm = (((1/0.521– 1/3.521) * 0.2055 * (6 + 4*0.72) * 110 * 1288) / 0.819) / 100,067

= 5.16 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

255 Weighted based on number of occupied residential housing units in each zone.
256 Average efficiency of boiler units found in Ameren PY3-PY4 data.
257 See: https://energy-models.com/pipe-sizing-charts-tables (last accessed 5/7/21) for copper pipe sizes and https://www.garagesanctum.com/size-chart/pex-tubing-size-chart/ (last accessed 5/7/21) for PEX pipe sizes.
258 Laboratory measured values from Hoeschele and Weitzel (2012), Figure 1.
259 Calculated using the average pipe thickness (I.D. + O.D.)*0.5.

following new baseline system efficiency assumptions:

Efficiency Assumption	System Type	New Baseline Efficiency
ηHeat	Boiler	84% AFUE

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 13 years.[260] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-PINS-V05-220101

REVIEW DEADLINE: 1/1/2025

260 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.

5.3.3 Central Air Conditioning

DESCRIPTION

This measure characterizes:

a) Time of Sale:

   a. The installation of a new residential sized (<= 65,000 Btu/hr) Central Air Conditioning ducted split system meeting ENERGY STAR SEER 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).[261]
   - All other conditions will be considered Time of Sale.

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

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

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown.[262]

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

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[261] 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.

[262] 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.

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

The baseline for the early replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.[263]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years.[264]

Remaining life of existing equipment is assumed to be 6 years.[265]

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below:[266]

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

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume defaults below.[267]

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 $3,140.[268] This cost should be discounted to present value using the nominal societal discount rate.

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263 Baseline SEER and EER should be updated when new minimum federal standards become effective.
264 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
265 Assumed to be one third of effective useful life
266 Based on incremental cost results from Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016.
267 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.
268 Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator, $2,857, and applying

Quality Installation: The additional design and installation work associated with quality installation has been estimated to cost an additional $150.[269]

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 capacity market.

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour) = 68%[270]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period) = 46.6%[271]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

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

Early replacement:[272]

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

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

ΔkWH for remaining measure life (next 12 years):

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

Where:

FLHcool = Full load cooling hours

---

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.

[269] Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers in Iowa.

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

[271] 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.

[272] 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).

= dependent on location and building type:[273]

Climate Zone (City based upon)	FLHcool (single family)	FLHcool (multifamily)	FLH_cooling (weatherized multifamily)[274]
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[275]	629	564	362

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

Capacity = Size of new equipment in Btu/hr (note 1 ton = 12,000Btu/hr)

= Use actual when program delivery allows size of AC unit to be known. If unknown, assume 33,600 Btu/hr for single family homes, 28,000 Btu/hr for multifamily, or 24,000 Btu/hr for mobile homes.[276] If building type is unknown, assume 31,864Btu/hr.[277]

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

= 13 [278]

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 (maximum of 30 years) to account for degradation over time,[279] or, if unknown, assume 9.3.[280]

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

= Actual, or 15 if unknown.

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273 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.

274 *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.

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

276 Single family cooling capacity based on Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), October 19, 2010, ComEd, Navigant Consulting. Multifamily capacity based on weighted average of PY9 Ameren and ComEd MF cooling capacities. Mobile home capacity based on ENERGY STAR's Manufactured Home Cooling Equipment Sizing Guidelines which vary by climate zone and home size. The average size of a mobile home in the East North Central region (1,120 square feet) from the 2015 RECS data is used to calculated appropriate size.

277 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.

278 Based on Minimum Federal Standard.

279 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

SEERadj = Adjustment percentage to account for in-situ performance of the unit[281]

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

$DeratingCool_{Eff}$ = Efficent Central Air Conditioner Cooling derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown[282]

$DeratingCool_{Base}$ = Baseline Central Air Conditioner Cooling derating

= 10%

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

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

= 0.959

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

= 392 kWh

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

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

= 546 kWh

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

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

= 1,316 kWh

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

= 546 kWh

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

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

Early replacement:[283]

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

[281] 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'.

[282] 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.

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

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

ΔkW for remaining measure life (next 12 years):

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

Where:

EERbase = EER Efficiency of baseline unit

= 10.5 [284]

EERexist = EER Efficiency of existing unit

= Use actual EER rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.[285] If unknown, assume 7.5.[286]

EERee = EER Efficiency of ENERGY STAR unit

= Actual installed or 12 if unknown

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

= 68%[287]

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

= 46.6%[288]

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

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

= 0.550 kW

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

= 0.377 kW

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

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

= 1.587 kW

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

= 0.550 kW

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

= 1.087 kW

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

= 0.377 kW

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[284] 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'.

[285] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

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

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

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-HVC-CAC1-V09-210101

Review Deadline: 1/1/2023

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 the Energy Conservatory website. See 'The Energy Conservatory_Blower-Door-Subtraction-Method.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'; See '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).[289]

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of this measure is 20 years.[290]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years.[291] See section below for detail.

DEEMED MEASURE COST

The actual duct sealing measure cost should be used.

LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

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

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[289] 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

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

[291] 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.

COINCIDENCE FACTOR

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

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

= 68%[292]

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

= 46.6%[293]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Modified Blower Door Subtraction

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

Where:

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

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

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

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

Where:

0.64 = Converts CFM50 to CFM25[294]

SLF = Supply Loss Factor

= % leaks sealed located in Supply ducts * 1 [295]

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

[293] 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.

[294] 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).

[295] Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a

Default = 0.5[296]

RLF = Return Loss Factor

= % leaks sealed located in Return ducts * 0.5[297]

Default = 0.25[298]

c) Calculate Electric Energy Savings:

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

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

ΔkWh_{Fan} = (ΔTherms * F_e * 29.3)

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25

= calculated above

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

=Actual

12,000 = Converts Btu/H capacity to tons

400 = Converts capacity in tons to CFM (400CFM / ton)[299]

FLHcool = Full load cooling hours

= Dependent on location as below:[300]

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[301]	629	564

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

TRFcool = Thermal Regain Factor for cooling by space type

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'.

296 Assumes 50% of leaks are in supply ducts.

297 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'.

298 Assumes 50% of leaks are in return ducts.

299 This conversion is an industry rule of thumb; e.g. see 'Why 400 CFM per ton.pdf'.

300 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.

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

= 1.0 for Unconditioned Spaces

= 0.4 for Semi-Conditioned Spaces[302]

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[303]	66%

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume the following:[304]

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
Unknown (for use in program evaluation only)	10.5

ΔTherms = Therm savings as calculated in Natural Gas Savings

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

= 3.14%[305]

29.3 = kWh per therm

302 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.

303 Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

304 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.

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

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

Before: $CFM50_{Whole\ House}$ = 4800 CFM50

$CFM50_{Envelope\ Only}$ = 4500 CFM50

House to duct pressure of 45 Pascals. = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4600 CFM50

$CFM50_{Envelope\ Only}$ = 4500 CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29

= 387 CFM

$CFM50_{DL\ after}$ = (4600 – 4500) * 1.39

= 139 CFM

Duct Leakage reduction at CFM25:

$\Delta CFM25_{DL}$ = (387 – 139) * 0.64 * (0.5 + 0.25)

= 119 CFM25

Energy Savings:

$\Delta kWh_{cooling}$ = [((119 / ((36,000/12,000) * 400)) * 730 * 36,000 * 1) / 1000 / 11] + (212 * 0.0314 * 29.3)

= 237 + 195

= 432 kWh

Heating savings for homes with electric heat:

$\Delta kWh_{heatingElectric}$ = (($\Delta CFM25_{DL}$ /((OutputCapacityHeat/12,000) * 400)) * FLHheat * OutputCapacityHeat * TRFheat *%ElectricHeat) / ηHeat / 3412

Where:

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

=Actual

FLHheat = Full load heating hours

= Dependent on location as below:[306]

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[307]	1,821

[306] 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.
[307] Weighted based on number of occupied residential housing units in each zone.

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[308]

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[309], use the following table:

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use:[310]

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
Unknown (for use in program evaluation only)[311]	N/A	N/A	1.28

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[308] 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.

[309] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

[310] 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.

[311] 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.

3412 = Converts Btu to kWh

For example, duct sealing in unconditioned space in a 36,000 Btu/H 2.5 COP heat pump heated single family house in Springfield with the blower door results described above:

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

= 734 kWh

Methodology 2: Evaluation of Distribution Efficiency

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

$\Delta kWh = ((((DE_{after} – DE_{before}) / DE_{after}) * FLHcool * CapacityCool * TRFcool * \%Cool)/1000 / \eta Cool) + (\Delta Therms * F_e * 29.3)$

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

FLHcool = Full load cooling hours

= Dependent on location as below:[312]

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[313]	629	564

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

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

=Actual

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.4 for Semi-Conditioned Spaces[314]

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program	66%

[312] 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.

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

[314] 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.

Central Cooling?	%Cool
evaluation only)[315]	

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume:[316]

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
Unknown (for use in program evaluation only)	10.5

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

DE_{before} = 0.85

DE_{after} = 0.92

Energy Savings:

$\Delta kWh_{cooling}$ = ((((0.92 – 0.85)/0.92) * 730 * 36,000 * 1 * 1) / 1000 / 11) + (212 * 0.0314 * 29.3)

= 182 + 195

= 377 kWh

Heating savings for homes with electric heat:

$\Delta kWh_{heatingElectric}$ = $((DE_{after} - DE_{before}) / DE_{after}))$ * FLHheat * OutputCapacityHeat * TRFheat * %ElectricHeat) / ηHeat / 3412

Where:

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

= Actual

FLHheat = Full load heating hours

= Dependent on location as below:[317]

Climate Zone (City based upon)	FLH_heat
1 (Rockford)	1,969
2 (Chicago)	1,840

[315] Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

[316] 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.

[317] Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.

Climate Zone (City based upon)	FLH_heat
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[318]	1,821

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[319]

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[320], use the following table:

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

COP = Coefficient of Performance of electric heating system[321]

= Actual. If not available use:[322]

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
Unknown (for	N/A	N/A	1.28

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

[319] 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.

[320] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

[321] Note that the HSPF of a heat pump is equal to the COP * 3.413.

[322] 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.

System Type	Age of Equipment	HSPF Estimate	COP Estimate
use in program evaluation only)[323]			

For example, duct sealing in unconditioned space in a 36,000 Btu/H, 2.5 COP heat pump heated single family house in Springfield with the following duct evaluation results:

DE_{after} = 0.92

DE_{before} = 0.85

Energy Savings:

$\Delta kWh_{heating}$ = ((0.92 – 0.85)/0.92) * 1,754 * 36,000 * 1 * 1) / 2.5) / 3412

= 563 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLHcool = Full load cooling hours:

= Dependent on location as below:[324]

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[325]	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%[326]

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

= 46.6%[327]

323 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.

324 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.

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

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

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

NATURAL GAS SAVINGS

For homes with Natural Gas Heating:

Methodology 1: Modified Blower Door Subtraction

ΔTherm = ((($\Delta CFM25_{DL}$ / (InputCapacityHeat * 0.0123)) * FLHheat * InputCapacityHeat * TRFheat * %GasHeat * (ηEquipment / ηSystem)) / 100,000

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25

InputCapacityHeat = Heating input capacity (Btu/hr)

=Actual

0.0123 = Conversion of Capacity to CFM (0.0123CFM / Btu/hr)[328]

FLHheat = Full load heating hours

=Dependent on location as below:[329]

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[330]	1,821

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[331]

%GasHeat = Percent of homes that have gas space heating

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[332], use the following table:

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[328] 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.

[329] 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.

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

[331] 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.

[332] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

100,000 = Converts Btu to therms

ηEquipment = Heating Equipment Efficiency

= Actual.[333] If not available, use 83%.[334]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[335]

= Actual. If not available, use 70%[336]

Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

333 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.

334 This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) = 0.829

335 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.

336 Estimated as follows: 0.829 * (1-0.15) = 0.70

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

Before: $CFM50_{Whole\ House}$ = 4800 CFM50

$CFM50_{Envelope\ Only}$ = 4500CFM50

House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4600 CFM50

$CFM50_{Envelope\ Only}$ = 4500CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29

= 387 CFM

$CFM50_{DL\ after}$ = (4600 – 4500) * 1.39

= 119 CFM

Duct Leakage reduction at CFM25:

$\Delta CFM25_{DL}$ = (387 – 139) * 0.64 * (0.5 + 0.25)

= 119 CFM25

Energy Savings:

Pre Distribution Efficiency = 1 – (387/4800) = 92%

ηSystem = 80% * 92% = 74%

ΔTherm = ((119/ (105,000 * 0.0123)) * 1,754 * 105,000 * 1 *(0.8/0.74)) / 100,000

= 183 therms

Methodology 2: Evaluation of Distribution Efficiency

$$\Delta Therm = ((DE_{after} - DE_{before}) / DE_{after})) * FLHheat * InputCapacityHeat * TRFheat * \%GasHeat * (\eta Equipment / \eta System)) / 100{,}000$$

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

Other factors as defined above.

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

DE_{after} = 0.92

DE_{before} = 0.85

Energy Savings:

ηSystem = 80% * 85% = 68%

ΔTherm = (((0.92 – 0.85)/0.92) * 1,754 * 105,000 * 1 * 1 * (0.8/0.68)) / 100,067

= 165 therm

Mid-Life Adjustment

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied.

For electric HVAC, to calculate the adjustment, re-calculate the savings using the algorithms in the 'Electric Energy Savings' section using the following new baseline system efficiency assumptions:

Efficiency Assumption	System Type	New Baseline Efficiency
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER
ηHeat	Heat Pump (8.2HSPF/3.413)	2.40 COP

For gas fueled systems, because the algorithm uses input capacity (which already accounts for the equipment efficiency), the *change* in equipment efficiency needs to be accounted for. Therefore re-calculate the savings using the following algorithm:

Methodology 1: Modified Blower Door Subtraction

ΔTherms = ((ΔCFM25$_{DL}$ / (InputCapacityHeat * 0.0123)) * FLHheat * InputCapacityHeat * TRFheat * %GasHeat * (ηEquipment / (ηEquipment$_{New}$ * DE$_{after}$)) / 100,000

Where:

ηEquipment$_{New}$ = 80% AFUE

DE$_{after}$ = Distribution efficiency after duct sealing

= 1 – (CFM50$_{DL\ After}$ / CFM50$_{Whole\ House\ After}$)

Methodology 2: Evaluation of Distribution Efficiency

ΔTherms = ((DE$_{after}$ – DE$_{before}$)/ DE$_{after}$)) * FLHheat * InputCapacityHeat * TRFheat * %GasHeat * (ηEquipment / (ηEquipment$_{New}$ * DE$_{after}$)) / 100,000

Where:

ηEquipment$_{New}$ = 80% AFUE

DE$_{after}$ = Distribution efficiency after duct sealing

= As evaluated using the Building Performance Institutes 'Distribution Efficiency Look-Up Table'

The re-calculated reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimated to be 10 years.[337] Note: if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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337 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-DINS-V10-220101

REVIEW DEADLINE: 1/1/2024

5.3.5 Furnace Blower Motor

DESCRIPTION

This measure describes savings from a brushless permanent magnet (BPM) motor (known and referred in this measure as an electronically commutated motor (ECM)) compared to a lower efficiency motor. Time of Sale and New Construction replacement scenarios no longer apply to this measure, as federal standards make ECM blower fan motors a requirement for residential furnaces.[338] Savings however are available from retrofitting an ECM motor into an existing furnace, or replacing an operational inefficient furnace with a new furnace with an ECM prior to the end of its life.

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.

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 through surveyed results of impacted homeowners.

Retrofitting an existing blower motor with a new ECM reduces the potential impact of the high efficiency motor over a new system designed for an ECM blower motor because existing systems were not designed to capitalize and take advantage of the ECM's multi-staging features. Energy and demand savings are limited to the efficiency gains from the motor itself.

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

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 6 years, which is the remaining life of existing furnaces.[339]

DEEMED MEASURE COST

The capital cost for this measure as a retrofit should be actual if known; if unknown, assume $322.[340] In cases of

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[338] As part of the code of federal regulations, energy conservation standards for covered residential furnace fans become effective on July 3, 2019 (10 CFR 430.32(y)). The expectation is the baseline will essentially become an ECM motor.

[339] While ECM blower motors have an effective useful life of 15 year (consistent with assumed life of a BPM/ECM motor, Appendix 8-E of the DOE Technical support documents for federal residential appliance standards) as this is a retrofit measure on an existing furnace blower motor, the remaining useful life of that equipment is used. For more detail, please see 5.3.7 Gas High Efficiency Furnace

[340] An incremental material cost of $97 was used and adapted from Tables 8.2.3 and 8.2.13 in the DOE Technical support documents for federal residential appliance standards. Furthermore, an incremental labor time of 2.5 hours at a per hour cost of $90 was included, bringing the total incremental cost to $322. For more detail on the source of the labor cost estimates, please see, "Evaluation of Retrofit Variable-Speed Furnace Fan Motors", NREL, January 2014 (page 27).

furnace early replacements, it is assumed the incremental cost of the ECM is $0.

LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

ECMs installed in high efficiency CACs and ASHPs do not generate peak demand cooling savings if demand savings are claimed for these systems. However, some savings are realized for fans operating in circulation mode, even during peak demand cooling periods. Circulation mode operation during peak cooling periods would only occur when a system is not operating in cooling mode, with the percent time in circulation mode calculated using the summer system peak and PJM peak coincidence factors. A metering study found 23% of fans operated continuously during the summer peak periods;[341] therefore, ECMs do generate some demand savings during peak periods (when the system is not cooling). ECMs installed with CACs or ASHPs not receiving a rebate improve the cooling efficiency and therefore generate additional peak demand savings (when the system is cooling). Demand savings vary with system size and can be calculated using factors listed in the demand savings calculation table in the next section which incorporate coincidence with peak in their calculation.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = Capacity_cooling * kWhSavingsPerTon

Where:

Capacity_cooling = Capacity of cooling system in tons

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

kWhSavingsPerTon = Blower fan kWh savings per ton of cooling[342]

The per-ton energy savings values vary by system installation scenario and location as provided below. Assumptions are also provided for installation with no or unknown cooling system.

Region	Existing ASHP	Existing CAC	Furnace, No Cooling System*	Furnace, Cooling System unknown* [343]
Rockford	247	229	210	223
Chicago	245	230	208	222

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

[342] 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'.

[343] 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)

Region	Existing ASHP	Existing CAC	Furnace, No Cooling System*	Furnace, Cooling System unknown* [343]
Springfield	249	231	203	221
Belleville	247	235	196	222
Marion	242	231	196	219
Average	247	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.				

For example, an BPM installed in an existing three ton, 16 SEER CAC in a home in Marion:

ΔkWh = 3 * 231

= 693 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Capacity_cooling * kWSavingsPerTon

Where:

kWSavingsPerTon = Blower fan kW savings per ton of cooling[344]

The per-ton energy savings values vary by system installation scenario and location as provided below. Assumptions are also provided for installation with no or unknown cooling system.

Demand Savings Type	Existing ASHP	Existing CAC	Furnace, No Cooling System*	Furnace, Cooling System unknown* [345]
SSP	0.085	0.085	0.013	0.065
PJM	0.064	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 in an existing three ton, 16 SEER CAC receiving a rebate in a home in Marion:

ΔkW_{ssp} = 3 * 0.0085

= 0.0255 kW

ΔkW_{pjm} = 3 * 0.064

= 0.192 kW

[344] 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'.

[345] 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)

NATURAL GAS SAVINGS

$$\Delta therms^{346} = - HeatingkWhSavings * 0.03412 / AFUE$$

Where:

HeatingkWhSavings = Heating kWh savings per ton of cooling[347]

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 64.4 AFUE% for the existing furnace.[348]

For example, an ECM installed in an existing three ton CAC and 95% AFUE furnace in a home in Marion:

Δtherms = (-39 kWh * 3 tons * 0.03412) / 0.95

Δtherms = - 4.2 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-FBMT-V07-220101

REVIEW DEADLINE: 1/1/2024

346 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.

347 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'.

348 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).[349]
   - All other conditions will be considered Time of Sale.

   The Baseline AFUE of the existing unit replaced:

   - If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 84%.
   - If the AFUE of the existing unit is unknown, use assumptions in variable list below ($AFUE_{Exist}$).
   - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown.[350]

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 90%

[349] 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.

[350] 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.

and input capacity less than 300,000 Btu/hr).[351]

DEFINITION OF BASELINE EQUIPMENT

Time of sale: The baseline equipment for this measure is a new, gas-fired, standard-efficiency water boiler. The baseline AFUE is assumed to be 84% and is based on minimum federal appliance standards for boilers manufactured on or after January 15, 2021.[352]

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[353]

Early replacement: Remaining life of existing equipment is assumed to be 8 years.[354]

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is dependent on tier:[355]

	Installation Cost	Incremental Install Cost
Baseline	$4,053	n/a
AFUE 90% (ENERGY STAR Minimum)	$5,519	$1,466
AFUE 95%	$6,188	$2,135

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 $4,627.[356] This cost should be discounted to present value using the nominal discount rate.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

351 ENERGY STAR Program Requirements, Product Specifications for Boilers, version 3.0, effective October 1, 2014 (≥ 90% AFUE for gas-fired and ≥ 87% AFUE for oil-fired)
352 Code of Federal Regulations, effective January 15, 2021 (10 CFR 432(e)(3)).
353 Appendix 8-F of the Department of Energy Commercial Technical Support Document, Table 8.3.3, federal residential appliance standards.
354 Assumed to be one third of effective useful life
355 Based on data provided in Federal Appliance Standards, Chapter 8.3, of DOE Technical Support Documents; Table 8.5.6 LCC and PBP Results for Hot-Water Gas Boilers (High Cost). Where efficiency ratings were not provided (AFUE 90% and 95%), the values are interpolated from those given.
356 $4,053 inflated using 1.91% rate.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Time of Sale:

$$\Delta Therms = (EFLH * CAP_{Input} * (AFUE_{Eff} / AFUE_{Base} - 1)) / 100{,}000$$

Early replacement:[357]

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

$$= (EFLH * CAPInput * (AFUE_{Eff} / AFUE_{Exist} - 1)) / 100{,}000$$

ΔTherms for remaining measure life (next 17 years):

$$= (EFLH * CAPInput * (AFUE_{Eff} / AFUE_{Base} - 1)) / 100{,}000$$

Where:

CAP_{Input} = Gas Boiler input capacity (Btuh)

= Actual

EFLH = Equivalent Full Load Hours for gas heating

Climate Zone (City based upon)	EFLH[358]
1 (Rockford)	1022
2 (Chicago)	976
3 (Springfield)	836
4 (Belleville)	645
5 (Marion)	656
Weighted Average[359]	928

$AFUE_{Exist}$ = Existing Boiler Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to

[357] 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).

[358] 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.

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

account for degradation over time,[360] or if unknown, assume 61.6 AFUE%.[361]

$AFUE_{Base}$ = Baseline Boiler Annual Fuel Utilization Efficiency Rating

= 84% if implemented in 2022 and beyond

$AFUE_{Eff}$ = Efficent Boiler Annual Fuel Utilization Efficiency Rating

= Actual. If unknown, use defaults dependent on tier as listed below:[362]

Measure Type	AFUE(eff)
ENERGY STAR®	90%
AFUE 90%	92.5%
AFUE 95%	95%

Time of Sale:

For example, a 100,000 Btu/h, 90% AFUE ENERGY STAR boiler purchased and installed near Springfield in 2022:

ΔTherms = (836 * 100,000 * (0.90/0.84 – 1)) / 100,000

= 59.7 Therms

Early Replacement:

For example, an existing function boiler with unknown efficiency is replaced with a 100,000 Btu/h, 90% AFUE ENERGY STAR boiler purchased and installed in Springfield in 2022:

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

= (836 * 100,000 * (0.90/0.616 – 1)) / 100,000

= 385.4 Therms

ΔTherms for remaining measure life (next 17 years):

= (836 * 100,000 * (0.90/0.84 – 1)) / 100,000

= 59.7 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GHEB-V09-220101

REVIEW DEADLINE: 1/1/2026

360 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

362 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.

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).[363]
  - All other conditions will be considered Time of Sale.

  The Baseline AFUE of the existing unit replaced:

  - If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
  - If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
  - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

  A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown.[364]

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

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[363] 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.

[364] 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 80% AFUE unit for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[365]

For early replacement: Remaining life of existing equipment is assumed to be 6 years.[366]

DEEMED MEASURE COST

Time of sale: The incremental installed cost (retail equipment cost plus installation cost) for this measure depends on efficiency as listed below:[367]

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
97%	$3873	$1862

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 80% baseline unit is assumed to be $2296.[368] 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

365 Table 8.3.3 The Technical support documents for federal residential appliance standards.

366 Assumed to be one third of effective useful life

367 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.

368 $2641 inflated using 1.91% rate.

has been estimated to take 1-2 hours (Tim Hanes, ESI). At $40/hr, VQI adds $60 to the installed cost.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electrical energy savings from the more fan-efficient (typically using brushless permanent magnet (BPM) blower motor) should also be claimed, please refer to “Furnace Blower Motor” characterization for details.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

If the blower motor is also used for cooling, coincident peak demand savings should also be claimed, please refer to “Furnace Blower Motor” characterization for savings details.

NATURAL GAS SAVINGS

Time of Sale:

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

Early replacement:[369]

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

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

ΔTherms for remaining measure life (next 14 years):

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

Where:

CAPInput = Gas Furnace input capacity (Btuh)

= Actual. If unknown, use the table below:

[369] 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).

Eligibility Tier	Input Capacity[370]
AFUE ≥ 95 (all furnaces, no tiers)	84,305
AFUE ≥ 95 and < 97 tier	84,000
AFUE ≥ 97 tier	87,796

EFLH = Equivalent Full Load Hours for gas heating

Climate Zone (City based upon)	EFLH[371]
1 (Rockford)	1022
2 (Chicago)	976
3 (Springfield)	836
4 (Belleville)	645
5 (Marion)	656
Weighted Average[372]	928

AFUE(exist) = Existing Furnace Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[373] or if unknown, assume 64.4 AFUE%.[374]

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

= 80%[375]

AFUE(eff) = Efficent Furnace Annual Fuel Utilization Efficiency Rating

= Actual. If unknown, , use the table below:

Eligibility Tier	AFUE (eff)[376]
AFUE ≥ 95 (all furnaces, no tiers)	96.0%
AFUE ≥ 95 and < 97 tier	95.9%
AFUE ≥ 97 tier	97.5%

Derating(base) =Baseline furnace AFUE derating

= 6.4%[377]

Derating(eff) =Efficent furnace AFUE derating

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370 Average Input Capacity for Northern Illinois, based on analysis of Nicor Gas 2019 Home Energy Efficiency Rebate Program participant tracking data, prepared by Guidehouse, Inc., based on 12,549 furnaces rebated at the 95 AFUE Tier, and 1,103 furnaces rebated at the 97 AFUE Tier. Approximately 10% of tracked input capacities were adjusted by Guidehouse based on verification of manufacturer model numbers. Values for Southern Illinois not available.

371 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.

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

373 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

375 Code of Federal Regulations, effective November, 2015 (10 CFR 432(e)).

376 Average AFUE based on analysis of Nicor Gas 2019 Home Energy Efficiency Rebate Program participant tracking data, prepared by Guidehouse, Inc., based on 12,549 furnaces rebated at the 95 AFUE Tier, and 1,103 furnaces rebated at the 97 AFUE Tier.

377 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.

=0% if verified quality installation is performed

=6.4% if verified quality installation is not performed or unknown[378]

Time of Sale:

For example, a 95% AFUE, 80,000Btuh furnace purchased and installed with verified quality installation for an existing home near Rockford:

ΔTherms = ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.8 * (1-0.064))) – 1)) / 100000

= 220 therms

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

ΔTherms = ((1022 * 80,000)/(1-0.064) * (((0.95 * (1-0.064)) / (0.8 * (1-0.064))) – 1)) / 100000

=164 therms

Early Replacement:

For example, an existing functioning furnace with unknown efficiency is replaced with an 95% AFUE, 80,000Btuh furnace using quality installation in Rockford:

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

= ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.644 * (1-0.064))) – 1)) / 100000

= 471 therms

ΔTherms for remaining measure life (next 14 years):

= ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.8 * (1-0.064))) – 1)) / 100000

= 220 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GHEF-V11-220101

REVIEW DEADLINE: 1/1/2025

[378] Ibid

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. Where unknown, the baseline should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.

c) Early Replacement/Retrofit:
   i. The early removal of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   ii. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   iv. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced, or
      - The existing unit requires minor repairs, defined as costing less than:[379]

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:

[379] 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	84% AFUE
Furnace	75% AFUE	80% AFUE
Ground Source Heat Pump	10 SEER	14 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 11.0 EER[380] 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, 10.5 EER[381]. If a gas water heater, the Federal Standard baseline is calculated as follows; 0.6483 – (0.0017 * storage capacity in gallons) for tanks<=55 gallons and 0.7897 − (0.0004 × storage capacity in gallons) for greater than 55 gallon storage water heaters.[382] 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,

380 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'.
381 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'.
382 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	84% 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).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[383]

For early replacement, the remaining life of existing equipment is assumed to be 6 years for ASHP and Central AC, 7 years for furnace, 8 years for boilers and GSHP[384] and 25 years for electric resistance.[385]

DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump (including any necessary electrical or distribution upgrades required) should be used (default of $3957 per ton),[386] minus the assumed installation cost of the baseline equipment ($1381 per ton for ASHP[387] or $2011 for a new baseline 80% AFUE furnace, or $4053 for a new 84% AFUE boiler,[388] and $952 per ton for new baseline Central AC replacement [389]).

Early Replacement: The actual full installation cost of the Ground Source Heat Pump should be used (including any necessary electrical or distribution upgrades required). If the install cost is unknown a default is provided above, however because these assumptions do not include any additional costs that may be required for fuel switch scenarios, these defaults should not be used and actual costs should always be used for fuel switch measures.

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 $2,296 for a new baseline 80% AFUE furnace, or $4,627 for a new 84% AFUE boiler, and 1,047 per ton for new baseline Central AC replacement.[390] 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)[391]

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

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383 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.

384 Assumed to be one third of effective useful life of replaced equipment.

385 Assume full measure life (16 years) for replacing electric resistance as we would not expect that resistance heat would fail during the lifetime of the efficient measure.

386 Based on data provided in 'Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives'.

387 Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation.

388 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.

389 Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator.

390 All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.

391 The baseline for calculating electric savings is an Air Source Heat Pump.

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 two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period and is presented so that savings can be bid into PJM's capacity market.

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%[392]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[393]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS AND NATURAL GAS SAVINGS

Non-fuel switch measures:

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/EER_{PL})/1000] + [HeatLoad* (1/$HSPF_{base}$ – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

Fuel switch measures:

Fuel switch measures must produce positive total lifecycle fuel savings (i.e., reduction in Btus at the premises) in order to qualify. This is determined as follows (note for early replacement measures the lifetime savings should be calculated by calculating savings for the remaining useful life of the existing equipment and for the remaining measure life):

SiteEnergySavings (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – GSHPSiteHeatConsumed + GSHPSiteCoolingImpact + GSHPSiteWaterImpact

GasHeatReplaced = [(HeatLoad * 1/$AFUE_{base}$) / 1,000,000]

FurnaceFanSavings = (FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e) / 1,000,000

GSHPSiteHeatConsumed = [HeatLoad * (1/(COP_{PL} * 3.412))/1000] * 3412) / 1,000,000

GSHPSiteCoolingImpact = [FLHcool * Capacity_GSHPcool * (1/$SEER_{base}$ – 1/EER_{PL})/1000] * 3412) / 1,000,000

$GSHPSiteWaterImpact_{Gas}$ = ((%DHWDisplaced * ((1/EF_{Gas} * GPD * Household * 365.25 * γWater * (T_{OUT} –

[392] 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)'.

[393] 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.

T_{IN}) * 1.0) / 1,000,000)

GSHPSiteWaterImpact$_{Electric}$ = (%DHWDisplaced * ((1/EF$_{Elec}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) * 3412) / 1,000,000

If SiteEnergySavings calculated above is positive, the measure is eligible.

The appropriate savings claim is dependent on which utilities are supporting the measure as provided in a table below:

Measure supported by:	Electric Utility claims (kWh):	Gas Utility claims (therms):
Electric utility only	SiteEnergySavings * 1,000,000/3,412	N/A
Electric and gas utility (Note utilities may make alternative agreements to how savings are allocated as long as total MMBtu savings remains the same).	%IncentiveElectric * SiteEnergySavings * 1,000,000/3,412	%IncentiveGas * SiteEnergySavings * 10
Gas utility only	N/A	SiteEnergySavings * 10

Note for Early Replacement measures, the efficiency and Fe terms of the existing unit should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC, 6 years for furnace, 8 years for boilers or GSHP, 15 years for electric resistance), and the efficiency and Fe terms for a new baseline unit should be used for the remaining years of the measure. See assumptions below.

Where:

FLHcool = Full load cooling hours

Dependent on location as below:[394]

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily	FLH_cooling (weatherized multifamily) [395]
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[396]	629	564	362

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

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

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

SEERbase = SEER Efficiency of baseline unit. For early replacment measures, the actual SEER rating

[394] 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.

[395] *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.

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

where it is possible to measure or reasonably estimate should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC, 8 years for GSHP). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[397] or if unknown assume default provided below:

Baseline/Existing Cooling System	SEERbase		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	9.3[398]	14[399]	
Ground Source Heat Pump	14[400]	14	
Central AC	9.3[401]	13[402]	
No central cooling	13 [403]	13[404]	

EER_{PL} = Part Load EER Efficiency of efficient GSHP unit[405]

= Actual installed

HeatLoad = Calculated heat load for the building

= FLH_GSHPheat * Capacity_GSHPheat

FLH_GSHPheat = Full load hours of heat pump heating

Dependent on location as below:[406]

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[407]	1,821

[397] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).
[398] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[399] Minimum Federal Standard as of 1/1/2015
[400] Estimate of existing GSHP efficiency is based converting 12 EER (estimate based upon Navigant, 2018 "EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case") to SEER.
[401] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[402] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
[403] Assumes that the decision to replace existing systems includes desire to add cooling.
[404] Assumes that the decision to replace existing systems includes desire to add cooling.
[405] 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.
[406] 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.
[407] Weighted based on number of occupied residential housing units in each zone.

Capacity_GSHPheat = Heating Output Capacity of Ground Source Heat Pump (Btu/hr)

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

$HSPF_{base}$ =Heating System Performance Factor of baseline heating system (kBtu/kWh). For early replacement measures, use actual HSPF rating where it is possible to measure or reasonably estimate for the remaining useful life of the existing equipment (6 years for ASHP, 8 years for GSHP or 15 years for electric resistance). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[408] or if unknown assume default:

Baseline/ Existing Heating System	HSPF_base		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	5.54[409]	8.2	
Ground Source Heat Pump	8.2[410]	8.2	
Electric Resistance	3.41[411]		

COP_{PL} = Part Load Coefficient of Performance of efficient unit[412]

= 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%[413]

= 0% if no desuperheater installed

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

= Actual. If unknown or for new construction, assume federal standard:[414]

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

408 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

410 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.

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

412 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.

413 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.

414 Minimum Federal Standard as of 4/1/2015;.

= 45.5 gallons hot water per day per household/2.59 people per household[415]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[416]
Multifamily - Deemed	2.1[417]
Custom	Actual Occupancy or Number of Bedrooms[418]

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= 125°F

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

= 50.7°F [419]

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

3412 = Conversion from Btu to kWh

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating. For early replacement measures, use actual AFUE rating where it is possible to measure or reasonably estimate for the remaining useful life of the existing equipment (6 years for furnace, 8 years for boilers). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[420] or if unknown assume default:

Baseline/ Existing Heating System	AFUEbase		
	Early Replacement (Remaining useful life of existing equipment)[421]	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Furnace	64.4%	80%	80%
Boiler	61.6%	84%	84%

415 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

416 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

417 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

418 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.

419 Table 4 in Chen, et. al., "Calculating Average Hot Water Mixes of Residential Plumbing Fixtures", June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.

420 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

FurnaceFlag = 1 if system replaced is a gas furnace, 0 if not.

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

For Early Replacement (1st 6 years) F_e_Exist = 3.14%[422]

For New Construction, Time of Sale and early replacement (remaining 10 years) F_e_New = 1.88%[423]

$EF_{GAS\ EXIST}$ = Energy Factor (efficiency) of existing gas water heater

= Actual. If unknown, assume federal standard:[424]

For <=55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

For > 55 gallons 0.7897 − (0.0004 * storage capacity in gallons)

= If tank size unknown, assume 40 gallons and EF_Baseline of 0.58

3412 = Btu per kWh

%IncentiveElectric = % of total incentive paid by electric utility

= Actual

%IncentiveGas = % of total incentive paid by gas utility

= Actual

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

[423] New furnaces are required to have ECM fan motors installed. Comparing Eae to Ef for furnaces on the AHRI directory as above, indicates that Fe for new furnaces is on average 1.88%.

[424] Minimum Federal Standard as of 4/1/2015.

Non Fuel Switch Illustrative Examples

New Construction using ASHP baseline:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed with a 50 gallon electric water heater in single family house in Springfield:

ΔkWh = [730 * 36,000 * (1/14 – 1/19) / 1000] + [1754* 36,000 * (1/8.2 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-50.7) * 1)/3412)]

= 494 + 3494 + 1390

= 5378 kWh

Early Replacement

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed in single family house in Springfield with a 50 gallon electric water heater replacing an existing working Air Source Heat Pump with unknown efficiency ratings:

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

= [730 * 36,000 * (1/9.3 - 1/19) / 1000] + [1754 * 36,000 * (1/5.54 - 1/(4.4 * 3.412)) / 1000] + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-50.7) * 1)/3412)]

= 1443 + 7191 + 1390

= 10,024 kWh

ΔkWH for remaining measure life (next 17 years):

= (730 * 36,000 * (1/14 – 1/19) / 1000] + [1967 * 36,000 * (1/8.2 – 1/ (4.4 * 3.412)) / 1000] + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-50.7) * 1)/3412)]

= 494 + 3494 + 1390

= 5378 kWh

Fuel Switch Illustrative Example

[for illustrative purposes 50:50 Incentive is used for joint programs]

New construction using gas furnace and central AC baseline:

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:

SiteEnergySavings (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – GSHPSiteHeatConsumed + GSHPSiteCoolingImpact + GSHPSiteWaterImpact

GasHeatReplaced = (HeatLoad * 1/$AFUE_{base}$) / 1,000,000

= (1754 * 36,000 * 1/0.8) / 1,000,000 = 78.9 MMBtu

FurnaceFanSavings = (FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e_New) / 1,000,000

= (1 * 1754 * 36,000 * 1/0.8 * 0.0188) / 1,000,000

= 1.5 MMBtu

GSHPSiteHeatConsumed = (HeatLoad * 1/COP_{PL})/ 1,000,000

= (1754 * 36,000 * 1/4.4) /1,000,000 = 14.3 MMBtu

Continued on next page

Fuel Switch Illustrative Example continued

GSHPSiteCoolingImpact = (FLHcool * Capacity_GSHPcool * (1/$SEER_{base}$ – 1/EER_{PL})/1000 * 3412)/ 1,000,000

= (730 * 36,000 * (1/13 – 1/19) / 1000 * 3412) /1,000,000 = 2.2 MMBtu

$GSHPSiteWaterImpact_{Gas}$ = ((%DHWDisplaced * ((1/EF_{Gas} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 1,000,000)

= (0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-50.7) * 1)) / 1,000,000 = 7.7 MMBtu

SiteEnergySavings (MMBTUs) = 78.9 + 1.5 – 14.3 + 2.2 + 7.7 = 76.0 MMBtu (Measure is eligible)

Savings would be claimed as follows:

Measure supported by:	Electric Utility claims:	Gas Utility claims:
Electric utility only	76.0 * 1,000,000/3412 = 22,274 kWh	N/A
Electric and gas utility	0.5 * 76.0 * 1,000,000/3412 = 11,137 kWh	0.5 * 76.0 * 10 = 380 Therms
Gas utility only	N/A	76.0 * 10 = 760 Therms

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (Capacity_cooling * (1/EERbase - 1/EER_{FL}))/1000 * CF

Where:

EERbase = Energy Efficiency Ratio of baseline unit (kBtu/kWh). For early replacment measures, the actual EER rating where it is possible to measure or reasonably estimate should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.[425] If unknown, assume default provided below:

Baseline/Existing Cooling System	EER_base		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	7.5[426]	11[427]	
Ground Source Heat Pump	12	12	
Central AC	7.5[428]	10.5[429]	

[425] Justification for degradation factors can be found on page 14 of ‘AIC HVAC Metering Study Memo FINAL 2_28_2018’. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

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

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

[429] 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’.

Baseline/Existing Cooling System	EER_base		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
No central cooling	10.5[430]	10.5	

EER_{FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit [431]

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

= 72%[432]

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

= 46.6%[433]

New Construction or Time of Sale:

For example, a 3 ton unit with Full Load EER rating of 19:

ΔkW_{SSP} = (36,000 * (1/11.8 – 1/19))/1000 * 0.72

= 0.83 kW

ΔkW_{PJM} = (36,000 * (1/11 – 1/19))/1000 * 0.466

= 0.54 kW

Early Replacement:

For example, a 3 ton Full Load 19 EER replaces an existing working Air Source Heat Pump with unknown efficiency ratings in Marion:

ΔkW_{SSP} for remaining life of existing unit (1st 8 years):

= (36,000 * (1/7.5 – 1/19))/1000 * 0.72

= 2.09 kW

ΔkW_{SSP} for remaining measure life (next 17 years):

= (36,000 * (1/11.8 – 1/19))/1000 * 0.72

= 0.83 kW

ΔkW_{PJM} for remaining life of existing unit (1st 8 years):

= (36,000 * (1/7.5 – 1/19))/1000 * 0.466

= 1.35 kW

ΔkW_{PJM} for remaining measure life (next 17 years):

= (36,000 * (1/11.8 – 1/19))/1000 * 0.466

= 0.54 kW

[430] Assumes that the decision to replace existing systems includes desire to add cooling.

[431] 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.

[432] 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)'.

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

NATURAL GAS SAVINGS

Calculation provided together with Electric Energy Savings 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 GSHP projects per Section 16-111.5B, changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure. For Early Replacement measures, the efficiency terms of the existing unit should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC, 6 years for furnace, 8 years for boilers or GSHP, 15 years for electric resistance), and the efficiency terms for a new baseline unit should be used for the remaining years of the measure.

ΔTherms = [Heating Consumption Replaced] + [DHW Savings if gas]

= [(HeatLoad * 1/$AFUE_{base}$) / 100,000] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

ΔkWh = [FurnaceFanSavings] - [GSHP heating consumption] + [Cooling savings] + [DHW savings if electric]

= [FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e * 0.000293] - [(HeatLoad * (1/COP_{PL} * 3.412))/1000] + [(FLHcool * Capacity_GSHPcool * (1/SEERbase - 1/EER_{PL}))/1000] + [ElecDHW * %DHWDisplaced * ((1/EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings. [Note the calculation provides the annual savings for the first 6 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 7-25)]:

ΔTherms = [(HeatLoad * 1/$AFUE_{exist}$) / 100,000] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,067)]

= [1754 * 36,000 * 1/0.644) / 100,000] + [((1 – 0) * 0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,0067)]

= 980 + 74

= 1054 therms

ΔkWh = [FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e_Exist * 0.000293] - [(HeatLoad * (1/COP_{PL} * 3.412))/1000] + [(FLHcool * Capacity_GSHPcool * (1/SEERexist - 1/EER_{PL}))/1000] + [ElecDHW * %DHWDisplaced * (((1/EF_{ELEC}) * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

= [1 * 1754 * 3600 * 1/0.644 * 0.0314 * 0.000293] - [(1754 * 36,000 * (1/(4.4 * 3.412)))/ 1000] + [(730 * 36,000 * (1/9.3 - 1/19))/ 1000)] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-50.7) * 1)/3412)]

= 90 - 4206 + 1443 + 0

= -2673 kWh

MEASURE CODE: RS-HVC-GSHP-V11-220101

REVIEW DEADLINE: 1/1/2025

5.3.9 High Efficiency Bathroom Exhaust Fan

DESCRIPTION

This market opportunity measure is split into the purchase of a new bathroom fan for typical usage, and to meet the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes fan capacities between 10 and 200 CFM rated at a sound level of less than 2.0 sones at 0.1 inches of water column static pressure, or 50 CFM if used for continuous ventilation. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

New efficient ENERGY STAR or ENERGY STAR Most Efficient exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2 – 2016.[434] ENERGY STAR specifications (effective October 1, 2015) and 2018 Most Efficient specifications are provided below:

Efficiency Level	Fan Capacity	Minimum Efficacy Level (CFM/Watts)	Maximum Allowable Sound Level (sones)
ENERGY STAR	10 – 89 CFM	2.8	2.0
	90 – 200 CFM	3.5	
ENERGY STAR Most Efficient	All	10	

DEFINITION OF BASELINE EQUIPMENT

New standard efficiency exhaust-only ventilation fan.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 19 years.[435]

DEEMED MEASURE COST

Incremental cost per installed fan is $43.50 for quiet, efficient fans.[436]

LOADSHAPE

Loadshape R11 - Residential Ventilation

COINCIDENCE FACTOR

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

[434] Bi-level controls may be used by efficient fans larger than 50 CFM
[435] 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.
[436] VEIC analysis using cost data collected from wholesale vendor.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

CFM = Nominal Capacity of the exhaust fan

= Actual or use defaults provided below

= Assume 50CFM for continuous ventilation[437]

$\eta_{BASELINE}$ = Average efficacy for baseline fan (CFM/watts)

= See table below

$\eta_{EFFCIENT}$ = Average efficacy for efficient fan (CFM/watts)

= Actual or use defaults provided below

Hours = assumed annual run hours,

= 1089 for standard usage[438]

= 8766 for continuous ventilation.

Defaults provided below:[439]

Application	Min CFM	Max CFM	Average CFM	Base CFM/Watts	ENERGY STAR CFM/Watts	ENERGY STAR ΔkWh Savings	ENERGY STAR Most Efficient CFM/Watts	ENERGY STAR Most Efficient ΔkWh Savings
Standard usage	10	89	70.6	1.7	4.9	28.9	12.0	38.2
	90	200	116.1	2.6	5.6	25.3	13.9	38.7
	Unknown		92.4	2.2	5.3	27.4	12.9	38.6
Continuous usage	N/A		50	1.7	5.1	170.7	11.2	216.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor

= 0.135 for standard usage

= 1.0 for continuous operation

Other variables as defined above

[437] 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.
[438] Assumed to be consistent with Residential Indoor Lighting hours of use.
[439] Based on review of Bathroom Exhaust Fan product available on CEC Appliance Database, accessed 6/18/2018. See 'CEC Bath Fan.xls' for more information.

Application	Min CFM	Max CFM	Average CFM	ENERGY STAR ΔkW Savings	ENERGY STAR Most Efficient ΔkW Savings
Standard usage	10	89	70.6	0.0036	0.0047
	90	200	116.1	0.0031	0.0048
	Unknown		92.4	0.0034	0.0048
Continuous usage	N/A		50	0.0195	0.0247

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-BAFA-V02-190101

REVIEW DEADLINE: 1/1/2024

5.3.10 HVAC Tune Up (Central Air Conditioning or Air Source Heat Pump)

DESCRIPTION

This measure involves the measurement of refrigerant charge levels and airflow over the central air conditioning or heat pump unit coil, correction of any problems found and post-treatment re-measurement. Measurements must be performed with standard industry tools and the results tracked by the efficiency program.

Savings from this measure are developed using a reputable Wisconsin study. It is recommended that future evaluation be conducted in Illinois to generate a more locally appropriate characterization.

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

DEFINITION OF EFFICIENT EQUIPMENT

N/A

DEFINITION OF BASELINE EQUIPMENT

This measure assumes that the existing unit being maintained is either a residential central air conditioning unit or an air source heat pump that has not been serviced for at least 3 years.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 3 years.[440]

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 $225.[441]

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 capacity market.

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

= 68%[442]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

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440 Based on DEER 2014 EUL Table for "Clean Condenser Coils – Residential" and "Refrigerant Charge – Residential".

441 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. The average value of $175 has been increased by inflation to give an estimate of $225 in 2021.

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

= 72%[443]

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

= 46.6%[444]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

Where:

FLHcool = Full load cooling hours

Dependent on location as below:[445]

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[446]	629	564

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

Capacity_cooling = Cooling cpacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)

= Actual

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

= Actual. If unknown assume 10 SEER [447]

MFe = Maintenance energy savings factor

= 0.05[448]

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

443 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)'.
444 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.
445 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.
446 Weighted based on number of occupied residential housing units in each zone.
447 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.
448 Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

= Actual. If unknown assume 10 SEER [449]

FLHheat = Full load heating hours

Dependent on location:[450]

Climate Zone (City based upon)	FLHheat
1 (Rockford)	2208
2 (Chicago)	2064
3 (Springfield)	1967
4 (Belleville)	1420
5 (Marion)	1445
Weighted Average[451]	1821

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

= Actual

$HSPF_{ASHP}$ = Heating Season Performance Factor of existing air source heat pump unit receiving maintenence

= Actual. If unknown assume 6.8 HSPF [452]

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

ΔkWh_{CAC} = (730 * 36,000 * (1/10))/1000 * 0.05

= 131 kWh

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

ΔkWh_{ASHP} = ((730 * 36,000 * (1/10))/1000 * 0.05) + (1967 * 36,000 * (1/6.8))/1000 * 0.05)

= 652 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW **=** Capacity_cooling * (1/EER)/1000 * MFd * CF

Where:

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

449 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.

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

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

452 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.

= Calculate using Actual SEER

= - 0.02*SEER^2 + 1.12*SEER [453]

MFd = Maintenance demand savings factor

= 0.02 [454]

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

= 68%[455]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[456]

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

= 46.6%[457]

For example, maintenance of 3-ton, SEER 10 (equals EER 9.2) CAC unit:

ΔkW_{SSP} = 36,000 * 1/(9.2)/1000 * 0.02 * 0.68

= 0.0532 kW

ΔkW_{PJM} = 36,000 * 1/(9.2)/1000 * 0.02 * 0.466

= 0.0365 kW

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Conservatively not included.

MEASURE CODE: RS-HVC-TUNE-V06-210101

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453 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.

454 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.

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

456 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)'.

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

5.3.11 Programmable Thermostats

DESCRIPTION

This measure characterizes the household energy savings from the installation of a new or reprogramming of an existing Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Because a literature review was not conclusive in providing a defensible source of prescriptive cooling savings from programmable thermostats, cooling savings from programmable thermostats are assumed to be zero for this version of the measure. It is not appropriate to assume a similar pattern of savings from setting a thermostat down during the heating season and up during the cooling season. Note that the EPA's EnergyStar program is developing a new specification for this project category, and if/when evaluation results demonstrate consistent cooling savings, subsequent versions of this measure will revisit this assumption.[458] Since energy savings are applicable at the household level, savings should only be claimed for one thermostat of any type (i.e., one programmable thermostat or one advanced thermostat), installation of multiple 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 is not: 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 16 years, however concerns over persistence over a population result in the application of a mid-life adjustment to reduce annual savings during the measure lifetime.[459] For reprogramming, the measure life of 2 years is assumed.

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown (e.g., through a retail program) the capital cost for the new installation measure is assumed to be $30.[460] The cost for reprogramming

[458] 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'.

[459] 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.

[460] 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.

is assumed to be $10 to account for the auditor's time to reprogram and educate the homeowner.

LOADSHAPE

Loadshape R09 - Residential Electric Space Heat

COINCIDENCE FACTOR

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh[461] = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + (ΔTherms * F_e * 29.3)

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	3%[462]

Elec_Heating_ Consumption

= Estimate of annual household heating consumption for electrically heated homes.[463] If location and heating type is unknown, assume 15,683 kWh.[464]

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

461 Note the second part of the algorithm relates to furnace fan savings if the heating system is Natural Gas.
462 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"
463 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.
464 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%[465]

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

Household Type	HF
Single-Family	100%
Mobile home	83%[466]
Multifamily	65%[467]
Unknown	96.5%[468]
Actual	Custom[469]

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%[470]

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

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

= 3.14%[471]

29.3 = kWh per therm

465 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.

466 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.

467 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

468 When Household type is unknown, a value of 96.5% may be used as a weighted average of 90% SF and 10% MF (96.5% = 100%*90% + 65%*10%) based on a Navigant evaluation of PY8 participants in ComEd's advanced thermostat program.

469 Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

470 "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness," GDS Associates, Marietta, GA. 2002GDS

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

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

ΔkWH = 1 * 17,794 * 0.062 * 100% * 100% + (0 * 0.0314 * 29.3)

= 1,103 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

NATURAL GAS ENERGY SAVINGS

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

Where:

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

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	97%[472]

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below:[473]

Climate Zone (City based upon)	Gas_Heating_ Consumption (therms)
1 (Rockford)	1,052
2 (Chicago)	1,005
3 (Springfield)	861
4 (Belleville)	664
5 (Marion)	676
Average	955

For example, a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

ΔTherms = 1.0 * 1005 * 0.062 * 100% * 100%

= 62.3 therms

[472] 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"

[473] 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.

Mid-Life Baseline Adjustment

Due to concerns that across a population the savings for programmable thermostats are likely to decline through the technical lifetime of the thermostat,[474] a mid-life adjustment should be applied. The mid-life adjustment should be applied in year 6 (i.e., after five years of full savings) and is calculated as 28%. This results in a consistent lifetime savings as applying a 50% reduction to the technical lifetime. This adjustment should be applied to both electric or therm heating savings.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-PROG-V08-220101

REVIEW DEADLINE: 1/1/2025

[474] This concern is based on consideration of the findings from a number of evaluations, including Sachs et al, *"Field Evaluation of Programmable Thermostats",* US DOW Building Technologies Program, December 2012, p35; "low proportion of households that ended up using thermostat-enabled energy saving settings", and Meier et al., *"Usability of residential thermostats: Preliminary investigations",* Lawrence Berkeley National Laboratory, March 2011, p1; "The majority of occupants operated thermostats manually, rather than relying on their programmable features and almost 90% of respondents reported that they rarely or never adjusted the thermostat to set a weekend or weekday program. Photographs of thermostats were collected in one on-line survey, which revealed that about 20% of the thermostats displayed the wrong time and that about 50% of the respondents set their programmable thermostats on "long term hold" (or its equivalent)."

5.3.12 Ductless Heat Pumps

DESCRIPTION

A heat pump provides heating or cooling by moving heat between indoor and outdoor air. This measure relates to a split heat pump with an outdoor unit and single or multi indoor units providing conditioned air.

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.[475]

This measure characterizes the following scenarios:

a) 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.
b) 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. Where unknown, the baseline should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition. 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/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

[475] 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.

- The existing unit requires minor repairs, defined as costing less than:[476]

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.

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[477]
Air Source Heat Pump	10 SEER	14 SEER
Central Air Conditioner	10 SEER	13 SEER
Boiler	75% AFUE	84% 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.

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

Deemed Early Replacement Rates For DMSHP

	Deemed Early Replacement Rate
Early Replacement Rate for DMSHP participants	27%[478]

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:

[476] 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.
[477] Based on relevant Federal Standards.
[478] Based on ComEd program data from 2018-2020 (1057 DMSHP installs).

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 EER.[479]

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, 10.5 EER. [480]

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 EER, 8.2 HSPF
Gas Furnace	80% AFUE
Gas Boiler	84% AFUE
Central AC	13 SEER, 10.5 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). Note that in order to claim cooling savings, there must be an existing air conditioning system.

For multifamily buildings, each residence must have existing individual heating equipment. Multifamily residences with central heating do not qualify for this characterization.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[481]

For early replacement, the remaining life of existing equipment is assumed to be 6 years for ASHP and Central AC, 7 years for furnace, 8 years for boilers[482] and 15 years for electric resistance.[483]

DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the DMSHP (including any necessary electrical or distribution upgrades required) should be used (defaults are provided below), minus the assumed installation cost of the baseline equipment ($1,381 per ton for ASHP,[484] or $2,011 for a new baseline 80% AFUE furnace, or $4,053 for a new 84% AFUE boiler,[485] and $952 per ton for new baseline Central AC replacement [486]).

Default full cost of the DMSHP is provided below. Note, for smaller units a minimum cost of $2,000 should be

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[479] 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'.

[480] 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'.

[481] Based on 2016 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[482] Assumed to be one third of effective useful life of replaced equipment.

[483] Assume full measure life (16 years) for replacing electric resistance as we would not expect that resistance heat would fail during the lifetime of the efficient measure.

[484] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation.

[485] 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.

[486] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator

applied:[487]

Unit Size	Full Install Cost ($/ton)[488]
9-9.9	$1,443
10-10.9	$1,605
11-12.9	$1,715
13+	$2,041

The incremental cost of the DSMHP compared to a baseline minimum efficiency DSMHP is provided in the table below:[489]

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 actual full installation cost of the DMSHP (including any necessary electrical or distribution upgrades required) should be used. 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 $2,296 for a new baseline 80% AFUE furnace or $4,627 for a new 84% AFUE boiler and $1,047 per ton for new baseline Central AC replacement.[490] If replacing electric resistance heat, there is no deferred replacement cost. 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 (including any necessary electrical or distribution upgrades required) should be used without a deferred replacement cost.

If the install cost is unknown a default is provided above, however because these assumptions do not include any additional costs that may be required for fuel switch scenarios, these defaults should not be used and actual costs should always be used for fuel switch measures.

LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling (if replacing gas heat and central AC)[491]

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

[487] 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.
[488] 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.
[489] Memo from Opinion Dynamics Evaluation Team, Ductless Mini-Split Heat Pumps: Incremental Cost Analysis, April 27, 2017
[490] All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.
[491] The baseline for calculating electric savings is an Air Source Heat Pump.

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 capacity market. Both values provided are based on metering data for 40 DMSHPs in Ameren Illinois service territory.[492]

For Single Zone DMSHPs providing supplemental or limited zonal cooling:

CF_{SSP} = Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)

= 43.1%[493]

CF_{PJM} = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

= 28.0%[494]

For Multi-Zone DMSHPs providing whole house cooling:

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%[495]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[496]

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS AND NATURAL GAS SAVINGS

Non fuel switch measures:

ΔkWh = [Cooling Savings] + [Heating Savings]

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

Fuel switch measures:

Fuel switch measures must produce positive total lifecycle fuel savings (i.e., reduction in Btus at the premises) in order to qualify. This is determined as follows (note for early replacement measures the lifetime savings should be calculated by calculating savings for the remaining useful life of the existing equipment and for the remaining measure life):

SiteEnergySavings (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – DMSHPSiteHeatConsumed + DMSHPSiteCoolingImpact

GasHeatReplaced = $(HeatLoad * 1/AFUE_{base}) / 1,000,000$

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492 All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015

493 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)'.

494 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.

495 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)'.

496 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.

FurnaceFanSavings = (FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e) / 1,000,000

DMSHPSiteHeatConsumed = ((HeatLoad * (1/$HSPF_{ee}$))/1000 * 3412) / 1,000,000

DMSHPSiteCoolingImpact = (($Capacity_{cool}$* $EFLH_{cool}$ * (1/$SEER_{Base}$ - 1/$SEER_{ee}$))/1000 * 3412) / 1,000,000

If SiteEnergySavings calculated above is positive, the measure is eligible.

The appropriate savings claim is dependent on which utilities are supporting the measure as provided in a table below:

Measure supported by:	Electric Utility claims (kWh):	Gas Utility claims (therms):
Electric utility only	SiteEnergySavings * 1,000,000/3,412	N/A
Electric and gas utility (Note utilities may make alternative agreements to how savings are allocated as long as total MMBtu savings remains the same).	%IncentiveElectric * SiteEnergySavings * 1,000,000/3,412	%IncentiveGas * SiteEnergySavings * 10
Gas utility only	N/A	SiteEnergySavings * 10

Note for Early Replacement measures, the efficiency and Fe terms of the existing unit should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC, 6 years for furnace, 8 years for boilers, 15 years for electric resistance), and the efficiency and Fe terms for a new baseline unit should be used for the remaining years of the measure. See assumptions below.

Where:

$Capacity_{cool}$ = the cooling output capacity of the ductless heat pump unit in Btu/hr[497]

= Actual installed

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. Depends on location. See table below:[498]

Climate Zone (City based upon)	$EFLH_{cool}$
1 (Rockford)	323
2 (Chicago)	308
3 (Springfield)	468
4 (Belleville)	629
5 (Marion)	549
Weighted Average[499]	364

$SEER_{base}$ = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh). For early replacment measures, the actual SEER rating where it is possible to measure or reasonably estimate should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC). If using rated efficiencies, derate efficiency value by 1% per year

[497] 1 Ton = 12 kBtu/hr

[498] *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.

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

(maximum of 30 years) to account for degradation over time,[500] or if unknown assume default provided below:

Baseline/Existing Cooling System	SEERbase		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	9.3[501]	14[502]	
Central AC	9.3[503]	13[504]	
Room AC	8.0[505]	13	
No central cooling	Make '1/SEER_exist' = 0 [506]	13[507]	

$SEER_{ee}$ = SEER rating of new equipment (kbtu/kwh)

= Actual installed[508]

HeatLoad = Calculated heat load being displaced

= $EFLH_{heat}$_DMSHP * Capacity_DMSHPheat

$EFLH_{heat}$_DMSHP = Ductless heat pump equivalent Full Load Hours for heating. Depends on location. See table below:

Climate Zone (City based upon)	$EFLH_{heat}$[509]
1 (Rockford)	1,520
2 (Chicago)	1,421
3 (Springfield)	1,347
4 (Belleville)	977
5 (Marion)	994
Weighted Average	1,406

[500] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).
[501] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[502] Minimum Federal Standard as of 1/1/2015
[503] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[504] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
[505] Estimated by converting the EER assumption for Room AC 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.
[506] 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.
[507] Assumes that the decision to replace existing systems includes desire to add cooling.
[508] 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.
[509] *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.

Capacity_DMSHPheat = Heating capacity of the ductless heat pump unit in Btu/hr

= Actual

$HSPF_{base}$ =Heating System Performance Factor of baseline heating system (kBtu/kWh) For early replacement measures, use actual HSPF rating where it is possible to measure or reasonably estimate for the remaining useful life of the existing equipment (6 years for ASHP, 15 years for electric resistance). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[510] or if unknown assume default:

Baseline/ Existing Heating System	$HSPF_{Base}$		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	5.54[511]	8.2[512]	
Electric Resistance	3.41[513]		

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating. For early replacement measures, use actual AFUE rating where it is possible to measure or reasonably estimate for the remaining useful life of the existing equipment (6 years for furnace, 8 years for boilers). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[514] or if unknown assume default:

Baseline/ Existing Heating System	AFUEbase		
	Early Replacement (Remaining useful life of existing equipment)[515]	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Furnace	64.4%	80%	80%
Boiler	61.6%	84%	84%

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

= Actual installed

FurnaceFlag = 1 if system replaced is a gas furnace, 0 if not.

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

For Early Replacement (1st 6 years) F_e_Exist = 3.14%[516]

For New Construction, Time of Sale and early replacement (remaining 10 years)

510 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

512 Based on Minimum Federal Standard effective 1/1/2015.

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

514 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

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

F_e_New = 1.88%[517]

3412 = Btu per kWh

%IncentiveElectric = % of total incentive paid by electric utility

= Actual

%IncentiveGas = % of total incentive paid by gas utility

= Actual

[517] New furnaces are required to have ECM fan motors installed. Comparing Eae to Ef for furnaces on the AHRI directory as above, indicates that Fe for new furnaces is on average 1.88%.

Non Fuel Switch Illustrative Examples

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:

ΔkWh_{heat} = (18000 * 1421 * (1/3.412 – 1/8))/1000 = 4,299 kWh

ΔkWh_{cool} = (18000 * 308 *(1/8.0 – 1/14)) /1000 = 297 kWh

ΔkWh = 4,299 + 297 = 4,596 kWh

Fuel Switch Illustrative Examples

[for illustrative purposes 50:50 incentive is used for joint programs]

Installing a 1.5-ton (heating and cooling capacity) ductless heat pump unit rated at 9 HSPF and 16 SEER in a single-family home in Chicago to displace gas furnace heat and replace a central air conditioner of unknown efficiency, savings are:

LifetimeSiteEnergySavings (MMBTUs) = LifetimeGasHeatReplaced + LifetimeFurnaceFanSavings – LifetimeDMSHPSiteHeatConsumed + LifetimeDMSHPSiteCoolingImpact

LifetimeGasHeatReplaced = ((HeatLoad * 1/$AFUE_{exist}$) / 1,000,000 * 6 years) + ((HeatLoad * 1/$AFUE_{base}$) / 1,000,000 * 9 years)

= ((1421 * 18,000 * 1/0.644) / 1,000,000 * 6) + ((1421 * 18,000 * 1/0.8) / 1,000,000 * 9)

= 526.1 MMBtu

LifetimeFurnaceFanSavings = ((FurnaceFlag * HeatLoad * 1/$AFUE_{exist}$ * F_e_Exist) / 1,000,000 * 6 years) + ((FurnaceFlag * HeatLoad * 1/$AFUE_{base}$ * F_e_New) / 1,000,000 * 9 years)

= ((1 * 1421 * 18,000 * 1/0.644 * 0.0314) / 1,000,000 * 6) + ((1 * 1421 * 18,000 * 1/0.8 * 0.0188) / 1,000,000 * 9)

= 12.9 MMBtu

LifetimeDMSHPSiteHeatConsumed = ((HeatLoad * (1/$HSPF_{ee}$))/1000 * 3412) / 1,000,000 * 15 years

= ((1421 * 18,000 * (1/9)) / 1000 * 3412)/1,000,000 * 15

= 145.5 MMBtu

LifetimeDMSHPSiteCoolingImpact = ((($Capacity_{cool}$* $EFLH_{cool}$ * (1/$SEER_{Exist}$ - 1/$SEER_{ee}$))/1000 * 3412) / 1,000,000 * 6 years) + ((($Capacity_{cool}$* $EFLH_{cool}$ * (1/$SEER_{Base}$ - 1/$SEER_{ee}$))/1000 * 3412) / 1,000,000 * 9 years)

= ((((308 * 18,000 * (1/9.3 – 1/16))/1000 * 3412)/1,000,000 * 6) + (((308 * 18,000 * (1/13 –1/16))/1000 * 3412) /1,000,000 * 9)

= 7.6 MMBtu

LifetimeSiteEnergySavings (MMBTUs) = 526.1 + 12.9 – 145.5 + 7.6

= 401.1 MMBtu (Measure is eligible)

Fuel Switch Illustrative Examples continued

First 6 years:

SiteEnergySavings_FirstYear (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – DMSHPSiteHeatConsumed + DMSHPSiteCoolingImpact

GasHeatReplaced = (HeatLoad * 1/$AFUE_{Exist}$) / 1,000,000

= (1421 * 18,000 * 1/0.644) / 1,000,000

= 39.7 MMBtu

FurnaceFanSavings = (FurnaceFlag * HeatLoad * 1/$AFUE_{Exist}$ * F_e_Exist) / 1,000,000

= (1 * 1421 * 18,000 * 1/0.644 * 0.0314) / 1,000,000

= 1.2 MMBtu

DMSHPSiteHeatConsumed = ((HeatLoad * (1/$HSPF_{ee}$))/1000 * 3412) / 1,000,000

= ((1421 * 18,000 * (1/9)) / 1000 * 3412)/1,000,000

= 9.7 MMBtu

DMSHPSiteCoolingImpact = (($Capacity_{cool}$* $EFLH_{cool}$ * (1/$SEER_{Exist}$ - 1/$SEER_{ee}$))/1000 * 3412) / 1,000,000

= ((308 * 18,000 * (1/9.3 – 1/16))/1000 * 3412)/1,000,000

= 0.9 MMBtu

SiteEnergySavings_FirstYear (MMBTUs) = 39.7 + 1.2 – 9.7 + 0.9 = 32.1 MMBtu

Remaining 9 years:

SiteEnergySavings_PostAdj (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – DMSHPSiteHeatConsumed + DMSHPSiteCoolingImpact

GasHeatReplaced = (1421 * 18,000 * 1/0.8) / 1,000,000

= 32.0 MMBtu

FurnaceFanSavings = (1 * 1421 * 18,000 * 1/0.8 * 0.0188) / 1,000,000

= 0.6 MMBtu

DMSHPSiteHeatConsumed = ((1421 * 18,000 * (1/9)) / 1000 * 3412)/1,000,000

= 9.7MMBtu

DMSHPSiteCoolingImpact = (((308 * 18,000 * (1/13 – 1/16))/1000 * 3412)/1,000,000

= 0.3 MMBtu

SiteEnergySavings_PostAdj (MMBTUs) = 32.0 + 0.6 – 9.7 + 0.3 = 23.2 MMBtu

Fuel Switch Illustrative Example continued

Savings would be claimed as follows:

Measure supported by:	Electric Utility claims:	Gas Utility claims:
Electric utility only	First 6 years: 32.1 * 1,000,000/3412 = 9408 kWh Remaining 10 years: 23.2 * 1,000,000/3412 = 6800 kWh	N/A
Electric and gas utility	First 6 years: 32.1 * 0.5 * 1,000,000/3412 = 4704 kWh Remaining 10 years: 23.2 * 0.5 * 1,000,000/3412 = 3400 kWh	First 6 years: 32.1 * 0.5 * 10 = 161 Therms Remaining 10 years: 23.2 * 0.5 * 10 = 116 Therms
Gas utility only	N/A	First 6 years: 32.1 * 10 = 321 Therms Remaining 10 years: 23.2 * 10 = 232 Therms

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = ((Capacity_{cool} * (1/EER_{base} - 1/EER_{ee})) / 1000) * CF$

Where:

EER_base = Energy Efficiency Ratio of baseline unit (kBtu/kWh). For early replacment measures, the actual EER rating where it is possible to measure or reasonably estimate should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.[518] If unknown assume default provided below:

Baseline/Existing Cooling System	EER_base		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Air Source Heat Pump	7.5[519]	11[520]	

518 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

520 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'.

Baseline/Existing Cooling System	EER_base		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Central AC	7.5[521]	10.5[522]	
Room AC	7.7[523]	10.5	
No central cooling	Make '1/EER_exist' = 0 [524]	10.5[525]	

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: [526]

= $(-0.02 * SEER^2) + (1.12 * SEER)$

For Single Zone DMSHPs providing supplemental or limited zonal cooling:

CF_{SSP} = Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)

= 43.1%[527]

CF_{PJM} = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

= 28.0%[528]

For Multi Zone DMSHPs providing whole house cooling:

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%[529]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[530]

NATURAL GAS SAVINGS

Calculation provided together with Electric Energy Savings above.

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

522 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'.

523 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."

524 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.

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

526 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.

527 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)'.

528 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.

529 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)'.

530 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

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. For Early Replacement measures, the efficiency terms of the existing unit should be used for the remaining useful life of the existing equipment (6 years for ASHP and Central AC, 6 years for furnace, 8 years for boilers or GSHP, 15 years for electric resistance), and the efficiency terms for a new baseline unit should be used for the remaining years of the measure.

ΔTherms = [Heating Consumption Replaced]

$= [(HeatLoad * 1/AFUE_{base}) / 100{,}000]$

ΔkWh = [FurnaceFanSavings] - [DMSHP heating consumption] + [Cooling savings]

$= [FurnaceFlag * HeatLoad * 1/AFUE_{base} * F_e * 0.000293] - [(HeatLoad * 1/HSPFee)/1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

MEASURE CODE: RS-HVC-DHP-V09-220101

REVIEW DEADLINE: 1/1/2025

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.

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

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

Definition of Efficient Equipment

To qualify for this measure an approved technician must complete the tune-up requirements listed below:[531]

- 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

Definition of Baseline Equipment

The baseline is furnace assumed not to have had a tune-up in the past 3 years.

Deemed Lifetime of Efficient Equipment

The measure life for the clean and check tune up is 3 years.[532]

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.

[531] American Standard Maintenance for Indoor Units (see 'HVAC Maintenance American Standard')
[532] Assumed consistent with other tune-up measures.

LOADSHAPE

Loadshape R09 - Residential Electric Space Heat

COINCIDENCE FACTOR

N/A

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = ΔTherms * F_e * 29.3

Where:

ΔTherms = as calculated below

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

= 3.14%[533]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \frac{(\text{CAPInputPre} * \text{EFLH} * (1/\ \text{Effbefore} - 1/\ (\text{Effbefore} + \text{Ei})))}{100{,}00}$$

Where:

$CAPInput_{Pre}$ = Gas Furnace input capacity pre tune-up (Btuh)

= Measured input capacity from HVAC SAVE

EFLH = Equivalent Full Load Hours for heating

Climate Zone (City based upon)	EFLH[534]
1 (Rockford)	1022
2 (Chicago)	976
3 (Springfield)	836
4 (Belleville)	645
5 (Marion)	656
Weighted Average[535]	928

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

534 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.

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

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-V06-210101

REVIEW DEADLINE: 1/1/2025

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.[536]

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 16 years, which is assumed to be the remaining life of the existing boiler.[537]

DEEMED MEASURE COST

The cost of this measure is $612.[538]

LOADSHAPE

NA

COINCIDENCE FACTOR

N/A

[536] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors, See ‘Boiler Reset Control – NaturalGasEfficiency.org’.

[537] This is intentionally longer than the assumptions found in the early replacement residential HVAC measures as the application of boiler reset controls will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

[538] Nexant. Questar DSM Market Characterization Report. August 9, 2006.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

NA

NATURAL GAS SAVINGS

ΔTherms = Gas_Boiler_Load * (1/AFUE) * Savings Factor

Where:

Gas_Boiler_Load[539]

= Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below.[540]

= or Actual if informed by site-specific load calculations, ACCA Manual J, or equivalent.[541]

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%[542]

[539] 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)

[540] 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.

[541] 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.

[542] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. See 'Boiler Reset Control – NaturalGasEfficiency.org'.

For example, boiler reset controls on a 92.5 AFUE boiler at a household in Rockford, IL

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-BREC-V03-210101

REVIEW DEADLINE: 1/1/2024

5.3.15 ENERGY STAR Ceiling Fan

DESCRIPTION

A ceiling fan/light unit meeting the efficiency specifications of ENERGY STAR version 4.0 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 into the component parts and should be claimed together. Lighting savings should be estimated utilizing the 5.5.9 LED Fixtures 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 or LED bulbs. Upon review of the ENERGY STAR Qualified Products List, it was determined that 88% of ceiling fans with integrated light kits leverage LED lamps; with the remaining 12% using CFLs.[543] Concurrently, ENERGY STAR criteria require ceiling fans with light kits to provide the consumer with either CFLs or LEDs. In the cases where light kits require screw-base sockets, the efficient lamps have to be included in the packaging of the ceiling fan.

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.

Effective January 21, 2020, all ceiling fan light kits manufactured after this date must be packaged with lamps to fill all screw-base sockets, further limiting the potential for inefficient light bulbs to be utilized. Additionally, ceiling fan light kits with pin-based sockets for fluorescent lamps must use electronic ballasts. Integrated ceiling fan light kits must adhere to the same lighting efficiency requirements.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The fan savings measure life is assumed to be 10 years.[544]

The lighting savings measure life is assumed to be 1 year for lighting savings for units installed in 2020 (see 5.5.9 LED Fixtures measure).[545]

DEEMED MEASURE COST

Incremental cost of a ceiling fan with light kit is $46.

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543 ENERGY STAR version 4.0, Product Specification for Residential Ceiling Fans and Ceiling Fan Light Kits, effective June 15, 2018. Qualified Products List data pulled on 10/11/2018.

544 Lifetime estimate is sourced from the ENERGY STAR Ceiling Fan Savings Calculator.

545 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.

Incremental cost of only a ceiling fan is $30.71. [546]

LOADSHAPE

R06 - Residential Indoor Lighting

R11 - Residential Ventilation

COINCIDENCE FACTOR

The summer peak coincidence factor for the ventilation savings is assumed to be 30%.[547]

For lighting savings, see 5.5.9 LED Fixtures measure.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

ΔkWh_{light} = see 5.5.9 LED Fixtures measure.

Where:[548]

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%

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546 The incremental cost of $46 is sourced from the ENERGY STAR Ceiling Fan Savings Calculator, which is based on a ceiling fan and a light kit. In order to determine the incremental cost of only a ceiling fan, the incremental cost of the lights were factored in and removed accordingly. Through review of the ENERGY STAR Qualified Products List, accessed on October 11, 2018, the average ceiling fan LED light kit had 1.2 lamps, with an average wattage of 11.8W. The comparable baseline wattage, baseline cost, and efficient lamp cost is based on a scaled equivalence from the 5.5.9 LED Fixtures measure.

547 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.

548 All fan operating conditions and baseline default assumptions are based upon assumptions provided in the ENERGY STAR Ceiling Fan Savings Calculator. The efficient wattages at the low and high speed settings are sourced from the average of available products on the ENERGY STAR Qualified Products List (QPL), as pulled on 10/11/2018. The efficient wattage at the medium speed is interpolated based on the varying speed wattages from the ENERGY STAR version 4.0 specifications. For more information on the QPL data set, please see “Illinois Residential Ceiling Fan Analysis.xlsx”.

$WattsMed_{base}$ = Fan wattage at Medium speed of baseline

= Actual. If unknown use 34 watts

$\%High_{base}$ = Percent of time spent at High speed of baseline

= 20%

$WattsHigh_{base}$ = Fan wattage at High speed of baseline

= Actual. If unknown use 67 watts

%LowES = Percent of time spent at Low speed of ENERGY STAR

= 40%

$WattsLow_{ES}$ = Fan wattage at Low speed of ENERGY STAR

= Actual. If unknown use 3 watts

$\%Med_{ES}$ = 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 13 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 31 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	3	13	31
ΔW	12	21	36

If the lighting WattsBase and WattsEE is unknown, assume the following:[549]

WattsBase =1.2 x 46.5 = 55.8 W

WattsEE = 1.2 x 11.8 = 14.2 W

549 Through review of the ENERGY STAR Qualified Products List, accessed on October 11, 2018, the average ceiling fan LED light kit had 1.2 lamps, with an average wattage of 11.8W. The comparable baseline is based on a scaled equivalent wattage from the 5.5.9 LED Fixtures measure.

For example, an ENERGY STAR ceiling fan with one, 22.4W LED lamp as part of its light kit were purchased and installed to replace an existing ceiling fan that was no longer operational, the savings are:

ΔkWh_{fan} = [365.25*3*((0.4*15)+(0.4*34)+(0.2*67))/1000] – [365.25*3*((0.4*3)+(0.4*13)+(0.2*3))/1000]

= 36.2 – 13.8 = 22.4 kWh

ΔkWh_{light} =((88.5 – 22.4)/1000) *759 * 1.06

= 53.2 kWh

ΔkWh = 22.4+53.2= 75.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

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

ΔkW_{Light} = see 5.5.9 LED Fixtures measure.

Where:

CF_{fan} = Summer Peak coincidence factor for ventilation savings

= 30%[550]

CF_{light} = Summer Peak coincidence factor for lighting savings

= 7.1%[551]

For example, an ENERGY STAR ceiling fan with one 22.4W LED lamp as part of its light kit were purchased and installed to replace an existing ceiling fan that was no longer operational, the savings are:

ΔkW_{fan} = ((67-31)/1000) * 0.3

= 0.0108 kW

ΔkW_{light} =((88.5 – 22.4)/1000) * 1.11 * 0.071

= 0.0052 kW

ΔkW = 0.0108 + 0.0052

= 0.016 kW

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See 5.5.9 LED Fixtures measure for bulb replacement costs.

550 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.

551 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

MEASURE CODE: RS-HVC-CFAN-V03-210101

REVIEW DEADLINE: 1/1/2023

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.[552] 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.[553] Since energy savings are applicable at the household level, savings should only be claimed for one thermostat of any type (i.e., one programmable thermostat or one advanced thermostat), and installation of multiple thermostats per home does not accrue additional savings.

Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regard to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[554] 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,[555] or an assumed mix of these two

[552] 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.

[553] 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'.

[554] 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.

[555] If the actual thermostat is programmable and it is found to be used in override mode or otherwise effectively being operated like a manual thermostat, then the baseline may be considered to be a manual thermostat

types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 51% programmed programmable and 49% manual or non-programmed programmable thermostats may be assumed.[556]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for advanced thermostats is assumed to be 11 years.[557]

DEEMED MEASURE COST

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used. For retail, Bring Your Own Thermostat (BYOT) programs,[558] or other program types, actual costs are still preferable,[559] but if unknown, then the average incremental cost for the new installation measure is assumed to be $125.[560]

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%[561]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[562]

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556 Based on Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013.

557 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.

558 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.

559 Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.

560 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.

561 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).

562 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

ΔkWh[563] = $\Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating}$ = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR_Heat + (ΔTherms * F_e * 29.3)

ΔkWh_{cool} = %AC * ((FLH * Capacity * 1/SEER)/1000) * Cooling_Reduction * Eff_ISR_Cool

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	3%[564]

Elec_Heating_Consumption

= Estimate of annual household heating consumption for electrically heated homes.[565] If location and heating type is unknown, assume 15,683 kWh.[566]

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

Heating_Reduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat including accounting for Thermostat

563 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.

564 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"

565 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.

566 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.

Optimization services[567]

Existing Thermostat Type	Heating_Reduction[568]
Manual	10.2%
Programmable	7.1%
Unknown (Blended)	8.5%

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

Household Type	HF
Single-Family	100%
Mobile home	83%[569]
Multifamily	65%[570]
Actual	Custom[571]
Unknown	96.5%[572]

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

Eff_ISR_Heat = Effective In-Service Rate for heating, the percentage of thermostats installed and configured effectively for 2-way communication. Note that retrospective adjustments should be made during evaluation verification activities through the use of a realization rate if the program design does not ensure that each advanced thermostat is actually installed and/or if the evaluation determines that the advanced thermostat is not actually installed in the Program Administrator's service territory.

Program Delivery	Eff_ISR_Heat
Direct Install	100%
Other programs where not evaluated	100%[573]

567 This estimate is based on a consumption data analysis with matching to non-participants and is therefore net with respect to participant spillover and between net and gross with respect to free ridership. Like all consumption data analyses, it is gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to these factors will be determined as part of the annual SAG net-to-gross process.

568 These values represent adjusted baseline savings values (8.8% for manual, and 5.6% for programmable thermostats) as presented in Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'), and incorporate any inherent in service rate impact. These values are adjusted upwards in v9 to account for inclusion of Thermostat Optimization savings in an estimated 40% of future participants (based on reported share of Nest and ecobee participants and 2020 rates of Thermostat Optimization and including an assumed 90% ISR consistent with the Guidehouse cooling savings study). The basis for the Thermostat Optimization savings is Navigant "ComEd CY2018 Seasonal Savings Heating Season Impact Evaluation Report", March 2019.

These values are used as the basis for the weighted average savings value when the type of existing thermostat is not known. Using weightings updated from PY8 data, based upon baseline type, and allocating programmability into manual and programmable based upon programmed status yields a weighted new blend of 43% manual (or non-programmed programmable) and 57% programmed. Further evaluation and regular review of this key assumption is encouraged.

569 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.

570 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

571 Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

572 When Household type is unknown, a value of 96.5% may be used as a weighted average of 90% SF and 10% MF (96.5% = 100%*90% + 65%*10%) based on a Navigant evaluation of PY8 participants in ComEd's advanced thermostat program.

573 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.

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

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

= 3.14%[574]

29.3 = kWh per therm

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

Thermostat control of air conditioning?	%AC[575]
Yes	100%
No	0%
Unknown (AC-targeted program)	99%
Unknown (general program)	82.5%

FLH = Estimate of annual household full load cooling hours for air conditioning equipment based on location and home type. If climate zone is unknown, assume the weighted average for the relevant home type. If both climate zone and home type are unknown, assume 623 hours.[576]

Climate zone (city based upon)	FLH (single family) [577]	FLH (general multifamily) [578]	FLH_cooling (weatherized multifamily) [579]
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[580]	629	564	293

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

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

575 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 ;

576 When both climate zone and home type are unknown, a value of 623 hours may be used as a weighted average of 90% SF and 10% MF (623 = 629*90% + 564*10%) based on a Navigant evaluation of PY8 participants in ComEd's advanced thermostat program.

577 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.

578 Ibid.

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

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

Capacity = Size of AC unit.[581] (Note: One refrigeration ton is equal to 12,000 Btu/hr)

= Use actual when program delivery allows size of AC unit to be known. If unknown assume 33,600 Btu/hr for single family homes, 28,000 Btu/hr for multifamily or 24,000 Btu/hr for mobile homes.[582] If building type is unknown, assume 33,040 Btu/hr.[583]

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. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[584] or:

Cooling System	SEER[585]
Air Source Heat Pump	12
Central AC	

1/1000 = kBtu per Btu

Cooling_Reduction = Assumed average percentage reduction in total household cooling energy consumption due to installation of advanced thermostat including accounting for Thermostat Optimization:[586]

= 8.4% [587]

Eff_ISR_Cool = Effective In-Service Rate for cooling, the percentage of thermostats installed and

[581] 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.

[582] Single family cooling capacity based on Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), October 19, 2010, ComEd, Navigant Consulting. Multifamily capacity based on weighted average of PY9 Ameren and ComEd MF cooling capacities. Mobile home capacity based on ENERGY STAR's Manufactured Home Cooling Equipment Sizing Guidelines which vary by climate zone and home size. The average size of a mobile home in the East North Central region (1,120 square feet) from the 2015 RECS data is used to calculated appropriate size.

[583] Unknown is based on statewide weighted average of 90% single family and 10% multifamily, based on a Navigant evaluation of PY8 participants in ComEd's advanced thermostat program.

[584] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[585] Estimate based upon Navigant, 2018 "EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case"

[586] 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.

[587] The Cooling_Reduction assumption is based on a TAC agreement to weight the consumption data analysis result (econometric) and the adjusted ENERGY STAR method for estimating runtime savings for advanced thermostats with stakeholder assumptions about baseline behavior (ENERGY STAR), provided by Guidehouse in 2020. The econometric result (7.8%) is weighted at 90%, and the ENERGY STAR result (10-14% range taken as reasonable by stakeholders, however 14% is used to account for increased Thermostat Optimization) weighted at 10%.

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

The adjusted ENERGY STAR analysis is gross with respect to all components of net-to-gross (free ridership, and participant and non-participant spillover). The econometric analysis uses matching to future participants and is therefore gross with respect to free ridership. Like all consumption data analyses, it is net with respect to participant spillover and gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to these factors will be determined as part of the annual SAG net-to-gross process.

configured effectively for 2-way communication. Note that retrospective adjustments should be made during evaluation verification activities through the use of a realization rate if the program design does not ensure that each advanced thermostat is actually installed and/or if the evaluation determines that the advanced thermostat is not actually installed in the Program Administrator's service territory.

Program Delivery	Eff_ISR_Cool
Direct Install	100%
Other programs where not evaluated	90%[588]

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

$\Delta kWH = \Delta kWh_{heating} + \Delta kWh_{cooling}$

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

= 743kWh + 172 kWh

= 915 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = %AC * (Cooling_DemandReduction * Btu/hr * (1/EER)/1000) * EFF_ISR_Cool * CF

Where:

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

= 16.4%[589]

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

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

$EER = (-0.02 * SEER\_exist^2) + (1.12 * SEER\_exist)$ [590]

If SEER or EER rating unavailable, use:

[588] The 2020 Guidehouse evaluation indicated that 6.75% of participants installed the advanced thermostat out of state. An additional reduction is applied to account for purchases that are never installed. Based on the available data this is estimated as an additional 3.75%.

[589] The current Cooling_DemandReduction assumption is based on results presented on August 4th, 2020 from a Guidehouse econometric analysis and further refinements discussed throughout August.

The final value is based upon the non-weather normalized savings percentage, adjusted for selection bias, %AC and ISR, provided by the Guidehouse econometric results, and includes an additional adjustment to account for the anticipated growth in Thermostat Optimization savings, The estimate of cooling reduction factor includes an adjustment for apparent selection bias, per stakeholder request as part of a 2020 study by Guidehouse involving a consumption analysis of ComEd advanced thermostat rebate recipients. Guidehouse acknowledges that this adjustment is a coarse method of addressing potential bias, but believes that this adjustment may not be accurate or applicable for future studies of this type.

[590] From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

Cooling System	EER[591]
Air Source Heat Pump	10.5
Central AC	

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 34%[592]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[593]

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

ΔkW_{SSP} = 100% * (16.4% * 33,600 * (1/10.5)/1000) * 100% * 34%
= 0.1784 kW

ΔkW_{PJM} = 100% * (16.4% * 33,600 * (1/10.5)/1000) * 100% * 23.3%
= 0.1223 kW

NATURAL GAS ENERGY SAVINGS

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR_Heat

Where:

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

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	97%[594]

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below.[595]

591 Based on converting SEER assumption to EER.
592 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.)
593 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.)
594 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"
595 Values are based on adjusting the average household heating consumption (849 therms) for Chicago based on 'Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor', calculating inferred heating load by dividing by average efficiency of new in program units in the study (94.4%) and then applying standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24*0.92) + (0.76*0.8) = 0.83). This Chicago value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

Climate Zone (City based upon)	Gas_Heating_ Consumption (therms)
1 (Rockford)	1,052
2 (Chicago)	1,005
3 (Springfield)	861
4 (Belleville)	664
5 (Marion)	676
Average	955

Other variables as provided above.

For example, an advanced thermostat replacing a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

ΔTherms = 1.0 * 1005 * 7.1% * 100% * 100%

= 71.4 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ADTH-V07-220101

REVIEW DEADLINE: 1/1/2024

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.[596] 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 84% AFUE and a residential, natural gas-fueled, 0.5803 UEF storage water heater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 21.5 years.[597]

DEEMED MEASURE COST

The incremental measure cost is assumed to be $3,522.[598]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

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[596] 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”.

[597] 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.

[598] Northeast Energy Efficiency Partnerships. Incremental Cost Study Report. September 23, 2011. Incremental measure cost of $2,791.00 for a combination boiler and $2,461.00 for a high efficiency boiler sized at 110 Mbh. The percentage increase is applied to the current boiler incremental cost to provide a combination boiler cost of $3,521.72.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \Delta Therm_{Boiler} + \Delta Therm_{WH}$$

$$\Delta Therms_{Boiler} = (EFLH * CAP_{Input} * (AFUE_{Eff} / AFUE_{Base} - 1)) / 100,000$$

$$\Delta Therms_{WH} = (1/UEF_{Base} - 1/UEF_{Eff}) * (GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} – T_{IN}) * 1.0) / 100,000$$

Where:

CAP_{Input} = Gas Furnace input capacity (Btuh)

= Actual

EFLH = Equivalent Full Load Hours for gas heating

Climate Zone (City based upon)	EFLH[599]
1 (Rockford)	1022
2 (Chicago)	976
3 (Springfield)	836
4 (Belleville)	645
5 (Marion)	656
Weighted Average[600]	928

$AFUE_{Exist}$ = Existing boiler annual fuel utilization efficiency rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[601] or if unknown, assume 61.6 AFUE%.[602]

$AFUE_{Base}$ = Baseline boiler annual fuel utilization efficiency rating

= 84%

$AFUE_{Eff}$ = Efficent boiler annual fuel utilization efficiency rating

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599 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.

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

601 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

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

= Actual. If unknown, use defaults dependent on tier as listed below:[603]

Measure Type	$AFUE_{Eff}$
AFUE ≥ 90%	92.5%
AFUE ≥ 95%	95%

UEF_{Base} = Uniform Energy Factor rating for baseline equipment

= For ≤55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

= For >55 gallons: 0.7897 − (0.0004 × storage capacity in gallons)

= If tank size unknown for SF assume 40 gallons and UEF_{Base} of 0.58

= If tank size unknown for MF assume 30 gallons and UEF_{Base} of 0.54

Use Multifamily if: Building meets utility's definition for multifamily

UEF_{Eff} =Uniform Energy Factor rating for efficient combination boiler. This is assumed consistent with a condensing instantaneous gas-fired water heater.

= 0.933 [604]

GPD = Gallons per day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household [605]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[606]
Multifamily - Deemed	2.1[607]
Custom	Actual Occupancy or Number of Bedrooms[608]

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

603 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.

604 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.

605 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

606 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

607 Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

608 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.

= 50.7°F [609]

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

For example, a Rockford single-family home installing an 80,000 Btuh condensing combination boiler unit with boiler AFUE of 95%:

$\Delta Therms_{Boiler}$ = (1022 * 80,000 * (0.95/0.84 - 1))/100,000

$\Delta Therms_{WH}$ = (1/0.5803 – 1/0.933) * (17.6 * 2.56 * 365.25 * 8.33 * (125-50.7) *1.0)/100,000

ΔTherms = 107.1 + 66.4

= 173.5 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-V03-220101

REVIEW DEADLINE: 1/1/2023

[609] Table 4 in Chen, et. al., "Calculating Average Hot Water Mixes of Residential Plumbing Fixtures", June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.

5.3.18 Furnace Filter Alarm – Provisional Measure

Measure has been removed in v9.0 due to evaluation results showing filter alarms being ineffectual at indicating a dirty filter.

5.3.19 Thermostatic Radiator Valves – Provisional Measure

DESCRIPTION

Thermostatic Radiator Valves (TRVs) are installed on hydronic or steam radiators to provide temperature control within a room or space. The TRV is a self-regulating valve requiring no auxiliary power, allowing the user to set the temperature to their preferred set point. On hydronic and two-pipe steam systems, as the room temperature rises the valve head expands, blocking the flow of hot water or steam into the radiator. On a one-pipe steam system the TRVs are installed on the air vent and limit the amount of air escaping the radiator, which in turn limits the amount of steam filling the radiator.

The current measure is limited to retrofit application in Multifamily buildings. TRVs are particularly effective in large multifamily buildings where some rooms tend to be overheated resulting in tenants leaving windows open even in winter.

From limited evaluation results, savings appear to be dependent on being part of a whole system commissioning and balancing project.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the TRV is installed on an existing hydronic or steam heated radiator in a multifamily building.

DEFINITION OF BASELINE EQUIPMENT

The baseline is an existing hydronic or steam heated radiator without a TRV installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a TRV is estimated as 15 years.[610]

DEEMED MEASURE COST

The actual cost per TRV should be used. If unknown assume a measure cost of $200 for steam systems and $250 for hot water per TRV.[611] If the heating system is required to be drained, the full cost should be used and split between all TRVs installed.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

[610] Estimate based on assumption used in Department of Energy, Dentz et al, "Thermostatic Radiator Valve Evaluation", January 2015.
[611] Department of Energy, Dentz et al, "Thermostatic Radiator Valve Evaluation", January 2015, Table 2, Page 7.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

ΔTherms = Gas_Heating_Load/(μBoiler * #Radiators) * %TRVSavings

Where:

ΔTherms = Therm savings per TRV installed

Gas_Heating_Load = Estimated Gas heating Load per multi family unit.[612]

Climate Zone (City based upon)	Gas_Heating_ Load per Multi family unit (therms)
1 (Rockford)	567
2 (Chicago)	542
3 (Springfield)	464
4 (Belleville)	358
5 (Marion)	365
Average	**515**

μBoiler = AFUE Efficiency of the boiler system

= Actual. If unknown assume 75%

#Radiators = Number of radiators in the multifamily unit.

= Actual. If unknown estimated as five.

%TRVSavings = Estimate of heating consumption savings from installing a TRV[613]

= 15% when part of a system balancing project to address overheated spaces

= 5% if installed without system balancing

[612] This assumption is based on the Single Family Gas Heating Consumption for boiler values provided in 5.3.14 Boiler Reset Controls (based on Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor)* multiplied by a 65% adjustment factor, which is used to account for the expected lower multifamily heating consumption relative to single-family households due to overall household square footage and exposure to the exterior.

[613] Based on literature review of a limited number of studies available including:
Department of Energy, Dentz et al, "Thermostatic Radiator Valve Evaluation", January 2015.
NYSERDA "Thermostatic Radiator Valve Demonstration Project", 1995.
Lublin University of Technology Cholewa et al "Actual energy savings from the use of thermostatic radiator valves in residential buildings – Long term field evaluation", July 2017.

For example, a TRV is installed on three of five radiators in a multifamily unit with a central 75% AFUE hydronic boiler, as part of a system balancing project in Chicago.

ΔTherms per TRV = Gas_Heating_Load/(μBoiler * #Radiators) * %TRVSavings

= 542 / (0.75 * 5) * 0.15

= 21.7 Therms

Total of 19.6 * 3 = 65.1 Therms for the multi family unit

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-TRVS-V01-210101

REVIEW DEADLINE: 1/1/2023

5.3.20 Residential Energy Recovery Ventilator (ERV)

DESCRIPTION

Unconditioned outdoor air is typically warmer or cooler than desired by the occupants and is often also more humid than desired. A Residential ERV system provides necessary outdoor air ventilation while preheating or precooling the outdoor air, and, in some Residential ERV systems, pre-dehumidifying the outdoor air as well. This saves energy required for heating, cooling, and dehumidifying the residence.

An ERV generally comprises two fans (Exhaust and Outdoor Intake) that pass the two streams of air through a heat exchanger, which may be a fixed plate heat exchanger or a rotary heat recovery wheel. Sensible heat from the warmer air stream is transferred to the cooler air stream, thereby reducing the amount of heating energy or cooling energy needed to condition the outdoor air to desired indoor air temperature and humidity levels. The heat exchanger surfaces, in some ERV models, may be coated with a hydroscopic material that absorbs/releases or transfers latent moisture from one air stream to the other. This increases the overall energy transfer efficiency during humid summer months by partially dehumidifying moist outdoor air using the relatively drier indoor exhaust air. In the winter, this same effect serves to humidify the outdoor air, making the space more comfortable, but not saving significant energy.

The current measure serves all residential single family and Group R2, R3 and R4 dwellings of 3 stories or less, both existing and new, where ERV is not required to comply with energy code.

This measure was developed to be applicable to electric cooling systems and electric or natural gas heating systems in the following program types: RF, NC, TOS. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The Residential ERV, proposed for installation, must be listed in the Home Ventilation Institute's HVI-Certified Ratings Listing by its Brand and Model Number, and the HVI-Certified Ratings Listing must include the Model's Maximum CFM, ASRE (Adjusted Sensible Recovery Efficiency) and ATRE (Adjusted Total Recovery Efficiency) ratings values.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a residential HVAC system with no energy recovery ventilator installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of an ERV is estimated as 15 Years.[614]

DEEMED MEASURE COST

The actual cost of the ERV should be used. If unknown assume an incremental measure cost of $25.00 per Maximum CFM HVI-Certified Rating of proposed Brand and Model Number.[615]

LOADSHAPE

R10 Residential Electric Heating and Cooling.

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[614] State of Minnesota Technical Reference Manual, version 3, pp. 350+.
https://mn.gov/commerce/industries/energy/utilities/cip/technical-reference-manual/

[615] This installed cost amount is estimated by Leidos based on 2Q2021 list prices from SupplyHouse.com for a variety of ERVs of nominally 95-117 CFM capacity plus an estimated $2,000 per ERV for electrical and mechanical installation services, divided by the Maximum listed CFM specified in the Home Ventilating Institute's Certified Products Directory for the specific ERVs offered by SupplyHouse.com. Unit installed prices ranged from $24.27 to $28.93 per CFM based on the above.

COINCIDENCE FACTOR

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

$CF_{SSP\ SF}$ = Summer System Peak Coincidence Factor for ERV (during utility peak hour)

= 95%[616]

$CF_{PJM\ SF}$ = PJM Summer Peak Coincidence Factor for ERV (average during PJM peak period)

= 95%[617]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ERV Electric Heating Savings

If residence uses Electric heating,

ΔkWh_heating = 1.08 * HVI_Max_CFM * HDD60 * 24 * HVI_Rated_ASRE / ηHeat / 3412 * Daily_Hrs_Ventilation / 24 * %ElectricHeat

Where:

1.08 = Specific heat of air x density of inlet air @ 70F x 60 min/hr in BTU/hr-F-CFM

HVI_Max_CFM = HVI-Certified Maximum CFM of the Brand/Model of ERV proposed to be used[618]

If ERV Brand and Model are unknown, use the appropriate values in following Table of ERV Default Values[619]:

ERV Default Values:

	ERV Default Heating and Cooling CFM	ERV Default ASRE	ERV Default ATRE	ERV Default Watts
Single-family	114	70%	56%	94
Multi-family	64	65%	53%	49
Unknown Residence[620]	99	68%	55%	80
Custom	*Actual*	*Actual*	*Actual*	*Actual*

HDD60 = Heating Degree Days, base 60F, for the Climate Zone of Customer's site, from the

616 Based on 24 hr /day, 7 day/w operation.

617 Ibid.

618 Please see file 'HVIProd_ER.xlsx' for all related values. This is a lookup based on Customer inputs of ERV Brand and Model Number, which must match one of the HVI-Certified listings.

619 Table of ERV Default Values is based on all available ERV Certified Data from file 'HVIProd_ER.xlsx' published by Home Ventilating Institute (https://www.hvi.org/hvi-certified-products-directory/section-iii-hrv-erv-directory-listing/). This table lists certified values of 387 models of ERVs. The default values above assume that Single-family residences will install ERVs with Heating CFM > 75 and Multi-family residences will install ERVs with Heating CFM <= 75 cfm. The respective default values represent arithmetic averages of the respective HVI ERV values separated into these two ERV CFM ranges.

620 Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions, and States, 2009. 69% Multi-Family and 31% Single Family.

following Table [621, 622]

Table 1: Climate Variables - Deemed Values based on nearest city below to Customer's Site.[623]

Climate Zone	Climate Heating Factor (CHF)	Heating based on Sensible: HDD60	Cooling based on Sensible: CDD65	Heating Design Day DBT	Cooling Design Day DBT	Cooling Design Day OA Enthalpy	Heating Design Day OA Enthalpy	Cooling Design Day RA Enthalpy	Heating Design Day RA Enthalpy	ΔEnthalpy [624] (Btu-hr/lb)	Daily fan use[625]
1 - Rockford	58%	5,552	991	0.3	88.0	41.0	0.07	28.36	25.34	6,375	17.8
2 - Chicago	55%	4,919	1,018	4.4	88.5	40.8	1.06	28.36	25.34	7,243	18.9
3 - Springfield	48%	4,259	1,339	7.3	90.7	42.8	1.75	28.36	25.34	11,311	18.9
4 - Belleville	49%	4,139	1,426	12.7	92.7	43.3	3.05	28.36	25.34	11,885	18.4
5 - Marion	46%	4,139	1,426	12.1	92.7	44.5	2.90	28.36	25.34	11,885	18.4

24 = Number of Hours in a Day [626]

HVI_Rated_ASRE = HVI-Certified Adjusted Sensible Recovery Efficiency of the Brand/Model of ERV proposed to be used[627]

= If ERV Brand and Model are unknown, use default values in previous table of ERV Default Values.

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[628] or if not available refer to default table below:[629]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92

621 HDD values found in IL TRM v.9, volume 3, 5.1.8 are populated by Climate Zone nearest to the Customer's Site Address.
622 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.
623 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 determines that using the minimum standard is appropriate.
624 Base: 28.4 BTU/lb Return Air
625 Based on defrost oversizing factor.
626 Used to convert Annual HDD (F-Days) to total deltaT-hours (F-Hr) per year. Also used to convert daily ERV run hours to % runtime.
627 Please see file 'HVIProd_ER.xlsx' for all related values. This is a lookup based on Customer inputs of ERV Brand and Model Number, which must match one of the HVI-Certified listings.
628 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).
629 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown (for use in program evaluation only)[630]	N/A	N/A	1.28

3412 = Converts Btu to kWh

Daily_Hrs_Ventilation = Average annual daily ERV run time during which heat/cooling is being recovered, based on the assumption that ERV is selected to provide adequate ventilation rate when operated continuously on the coldest day of the year, when the defrost cycle interrupts heat recovery for a period of time depending on outdoor air temperature. ERV is assumed to be oversized so that on this coldest day, the ERV will provide the total ventilation air quantity during the minutes that is is not in defrost. As an example, if a coldest day results in 20% defrost time, the ERV is assumed to be selected at 1/0.8 or 125% oversizing. On the coldest day, the fan would operate 100% of the time. When not in defrost, it is assumed the homeowner would reduced fan operation to 80% runtime to avoid overventilating the residence. This assumed behavior results in an average annual runtime per day ranging from 17.8 to 18.9 hours/day.

The following defrost schedule is typical of ERV manufacturers and was used to calcuate average daily run hours:

OA DBT	Defrost	On	Total	% Runtime
27 F	3.0 Min.	25.0 Min.	28.0 Min.	89.3%
-4 F	4.5 Min.	17.0 Min.	21.5 Min.	79.1%
-31 F	7.0 Min.	15.0 Min.	22.0 Min.	68.2%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[631], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%

[630] 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.

[631] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People’s Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd’s 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
All DUs					**24%**

For example, assuming HVI Max CFM = 117 cfm; HDD60 = 5,552 (Rockford, IL); Electric Resistance Heat (COP=1.0); HVI Rated ASRE = 75%; Heating COP = 1.0; Daily_Hrs_Ventilation = 17.8; %ElectricHeat = 100%

ΔkWh_heating = ((1.08 * 117 * 5552 * 24) * 75% / 1.0 / 3412) * 17.8 / 24 * 100%

= 2742 kWh of heating energy saved

ERV Electric Cooling Savings

If residence uses Electric cooling, the cooling savings is calculated by the following equation:

ΔkWh_cooling = 4.5 * HVI_Max_CFM * ΔEnthalpy * 24 * HVI_Rated_ATRE / 1000 / ηCool * Daily_Hrs_Ventilation / 24 * %Cool

Where:

4.5 = Density of inlet air at 70F x 60 min/hr in lb-min/ft3 -hr

HVI_Max_CFM = HVI-Certified Maximum CFM of the Brand/Model of ERV proposed to be used[632]

= If ERV Brand and Model are unknown, use default values in previous "Table of ERV Default Values".

ΔEnthalpy = Difference between Outdoor Air and Return Air Enthalpies (Btu/lb air) for each weather bin of the Climate Zone of Customer's site[633] times the number of hours of occurrence per year of each weather bin

= Values contained in Table 1, above, for 5 representative climate zones

= $\sum$ [($H\_OA\_Cool_{bin}$ - $H\_RA\_Cool_{bin}$) * Annual $Hours_{bin}$] summed over all temperature bins where $H\_OA\_Cool_{bin} > H\_RA\_Cool_{bin}$.

Where:

H_OA_Cool = Weather Bin Outdoor Air Enthalpy

H_RA_Cool = Cooling Mode Return Air Enthalpy = 28.36 Btu/lb, a deemed value.

1000 = Conversion of btu to kbtu.

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

= Actual (where new or where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to

[632] Please see HVI Table at the end of this document. This is a lookup based on Customer inputs of ERV Brand and Model Number, which must match one of the HVI-Certified listings".

[633] This is based the Climate Zone based on the Customer's Site Address, informed by the Minnesota Technical Reference Manual v.3, page 350, commercial ERV measure assumptions modified for Illinois climate conditions using ASHRAE Design Data Tables. The table recreates enthalpy assumptions originating in the Minnesota TRM v3 for commercial ERV measure, page 350, tables 1 and 2, modified for Illinois climate conditions

account for degradation over time,[634] or if unknown assume the following:[635]

Age of Equipment	SEER Estimate
Window Air Conditioner	9
Central AC before 2006	10
Central AC 2006 - 2014	13
Central AC After 1/1/2015	13
Heat Pump After 1/1/2015	14
Unknown (for use in program evaluation only)	10.5

HVI_Rated_ATRE = HVI-Certified Adjusted Total Heat Recovery Efficiency of the Brand/Model of ERV proposed to be used[636].

Daily_Hrs_Ventilation = As previously defined

24 = Hours in a day

%Cool = Percent of homes that have cooling

Is Residence Cooled?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[637]	66%

For example, assuming HVI Max CFM = 117 cfm; ΔEnthalpy = 6,375 BTU-hr/lb (Rockford, IL); Air Conditioner, vintage older than 2006 (ηCool = 9.3); HVI Rated ATRE = 48%; Daily_Hrs_Ventilation = 17.8; %Cool = 100%

ΔkWh_cooling = 4.5 * 117 * 6375 / 1000 / 9.3 * 48% * 17.8 / 24 * 100%

= 128 kWh

ERV Fan Energy Savings

For all heating or heating/cooling ERV applications, the ERV fan savings represents the change in energy usage of the ERV fan annual energy use versus the base case standard (non-ERV) exhaust fan energy use.

The base case non-ERV exhaust fan energy use is deemed to be equal to the average ERV daily exhaust volume of air exhausted, times the deemed fan efficiency of a continuously-operated bathroom exhaust fan, as defined in Section 5.3.9 of IL-TRM_Effective_010122_v10.0_Vol_3_Res_08062021_DRAFT.docx: 1.7 CFM/Watt. The daily average total exhaust volume of the existing bathroom exhaust fan(s) is deemed to be equal to the proposed ERV daily average total exhaust volume, after taking into account the defrost cycle periods wherein ERV fan energy is consumed but no ventilation occurs.

Therefore:

634 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

635 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.

636 Please see file 'HVIProd_ER.xlsx' for all related values. This is a lookup based on Customer inputs of ERV Brand and Model Number, which must match one of the HVI-Certified listings.

637 Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

Exist_Exh_Fan_Use = HVI_Rated_CFM * Daily_Hrs_Ventilation / 24 / 1.7 CFM/Watt / 1000 * Daily_Fan_Use * 365.25

Where:

HVI_Rated_CFM = HVI-Certified Heating CFM at Maximum Air Flow of the Brand/Model of ERV proposed to be used[638]

= If ERV Brand and Model are unknown, use default values in previous "Table of ERV Default Values".

Daily_Hrs_Ventilation = As previously defined.

1.7 CFM/Watt = Deemed base case bathroom exhaust fan efficiency

24 = Hours in a Day

Daily_Hrs_Fan_Use = Deemed 24 hr/day because of continuous ERV fan use whether ERV is in defrost cycle or in ventilation cycle

365.25 = Days in a Year

1000 = Conversion of watts to kW

8766 = Annual Hours of Bathroom Fan Use

ERV_Fan_Use = HVI_Rated_W / 1000 * Daily_Hrs_Fan_Use * 365

Where:

HVI_Rated_W = HVI-Certified Wattage at Maximum Air Flow of the Brand/Model of ERV proposed to be used[639]

= If ERV Brand and Model are unknown, use default Watts/CFM in previous "Table of ERV Default Values" x ERV CFM (also from "Table of ERV Default Values").

1000 = Conversion of watts to kW

Daily_Hrs_Fan_Use = Deemed to be 24 hr/day because of continuous ERV fan use whether ERV is in defrost cycle or in ventilation cycle.

Savings (positive or negative) therefore are calculated by the following equation:

Exist_Exh_Fan_Use - ERV_Fan_Use

Where both terms in the equation are as previously defined.

[638] Please see file 'HVIProd_ER.xlsx' for all related values. This is a lookup based on Customer inputs of ERV Brand and Model Number, which must match one of the HVI-Certified listings.

[639] Please see file 'HVIProd_ER.xlsx' for all related values. This is a lookup based on Customer inputs of ERV Brand and Model Number, which must match one of the HVI-Certified listings".

For Example, assuming HVI_Rated_CFM = 117 CFM; HVI Rated Watts = 106 W; Daily_Hrs_Ventilation = 17.8; Daily_Hrs_Fan_Use = 24; Base Case Bathroom Exhaust Fan Efficiency = 1.7 CFM/Watt.

Exist_Exh_Fan_Use = 117 * 17.8 / 24 / 1.7 / 1000 * 24 * 365.25 = 447 kWh/Year

ERV_Fan_Use = 106 / 1000* 24 * 365.25 = 929 kWh

ERV Fan Energy Savings = 447 kWh - 929 kWh = - (482) kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh_{Annual}$ / HOU * CF * Daily_Hrs_Ventilation / 24

Where:

ΔkWh_{Annual} = ΔkWh_heating + ΔkWh_cooling

HOU = Annual Hours of Use of ERV, including defrost hours where fan recirculates indoor air through outdoor air heat exchanger.

= Actual. Use 8,766 hours/year if actual is not available.[640]

$CF_{SSP\ SF}$ = Summer System Peak Coincidence Factor for ERV (during utility peak hour)

= 95%[641]

$CF_{PJM\ SF}$ = PJM Summer Peak Coincidence Factor for ERV (average during PJM peak period)

= 95%[642]

Daily_Hrs_Ventilation = As defined previously.

24 = Hours in a day

For example, assuming Annual kWh Saved = 1989 kWh/year; HOU = 8,760 Hr/Yr; CF = 0.95; Daily_hr_use = 17.8

ΔkW = 1989 / 8766 * 0.95 * 17.8 / 24

= 0.16 kW

NATURAL GAS SAVINGS

$\Delta Therms_{Annual}$ = 1.08 * HVI_Max_CFM * HDD60 * 24 * HVI_Rated_ASRE / ηHeat / 100,000 * Daily_Hrs_Ventilation / 24 * %GasHeat

Where:

1.08 = Conversion of CFM air * delta T to BTU/hr

[640] Deemed continual operation of ERV throughout year.
[641] Based on 24 hr /day, 7 day/w operation.
[642] Ibid.

HVI_Max_CFM = HVI-Certified Maximum CFM of the Brand/Model of ERV proposed to be used[643]

HDD60 = Heating Degree Days base 60F, for the Climate Zone of Customer's site

= Value obtained from Table 1, above.

24 = Converts Days to Hours[644]

HVI_Rated_ASRE = HVI-Certified Adjusted Sensible Recovery Efficiency of the Brand/Model of ERV proposed to be used[645]

= If ERV Brand and Model are unknown, use default values in previous table of ERV Default Values.

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate, assuming 85% distribution efficiency if only equipment efficiency is available).[646] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[647] or if Equipment Efficiency is not available, use Section 5.3 to select the appropriate equipment efficiency for the project.

100,000 = Converts Btu/hr to Therms

%GasHeat = Percent of homes that have gas space heating

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[648], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

643 Please see file 'HVIProd_ER.xlsx' for all related values. This is a lookup based on Customer inputs of ERV Brand and Model Number, which must match one of the HVI-Certified listings.
644 Used to convert Annual HDD (F-Days) to total deltaT-hours (F-Hr) per year.
645 Please see file 'HVIProd_ER.xlsx' for all related values. This is a lookup based on Customer inputs of ERV Brand and Model Number, which must match one of the HVI-Certified listings.
646 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.
647 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).
648 Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

Other factors as defined above.

For example, assuming: HVI_Max_CFM =117; HDD60 = 5552; HVI_Rated_ASRE = 75%; ηHeat = 0.80 (Non-condensing Gas Heat); Daily_Hrs_Ventilation = 17.8, then

$\Delta Therms_{Annual}$ = 1.08 * 117 * 5552 * 24 * 75% / 0.80 / 100,000 * 17.8 / 24

= 117 Therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ERVS-V01-220101

REVIEW DEADLINE: 1/1/2025

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 either to the first length of both the hot and cold pipe (this is the most cost-effective section to insulate in non-circulating systems, since the water pipes act as an extension of the hot water tank) or to a hot water recirculating loop. 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. Where a hot water recirculating pump is in use, this measure is viable for the entire hot water loop.

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

The baseline is an un-insulated hot water pipe.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years.[649]

Deemed Measure Cost

The actual installation cost should be used if known. If unknown, the measure cost including material and installation is assumed to be $3 per linear foot.[650] For foam pipe insulation assume a measure cost of $0.26/ft for ½" insulation and $0.31/ft for ¾" insulation.[651]

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:

$$\Delta kWh = ((1 / R_{exist} - 1 / R_{new}) * C_{inside} * L_{effective} * \Delta T * 8{,}766 * ISR) / \eta DHW / 3412$$

[649] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[650] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
[651] Review of website cost data for Homedepot.com, Lowes.com, and Menards.com for locations in Peoria, IL.

Where:

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

= Varies based on pipe size and material. See table below for values.

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

= Actual (R_{exist} + R value of insulation[652])

C_{inside} = Inside circumference of the pipe [ft]

= Actual (0.5" pipe = 0.1427 ft, 0.75" pipe = 0.2055 ft); See table below for values.

$L_{effective}$ = Effective length of pipe from water heating source covered by pipe insulation (ft) [653]

= $L_{Horizontal} + \alpha L_{Vertical}$

= Actual; See table below for α values. If unknown, assume 3ft of vertical and remaining horizontal.

ΔT = Average temperature difference between supplied water and outside air temperature (°F)

= 60°F [654]

8,766 = Hours per year

ISR = In Service Rate

= 0.56 for Kits distribution,[655] 0.78 for Virtual Assessment followed by Self-Installation[656], and 1.0 for Direct Install, TOS, or Verified Install program types

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [657]

3412 = Conversion from Btu to kWh

Parameter assumptions for various pipe sizes and materials:

[652] Where possible it should be ensured that the R-value of the insulation is at the appropriate mean rating temperature (100F).

[653] In cases with zero wind, heat loss (and therefore) savings is larger from horizontal pipe configurations than vertical pipe configurations due, perhaps to the way in which convective losses are handled. Given that most DHW pipe insulation installations begin with a vertical orientation from the water heater, an adjustment to the engineering calculation is needed. An analysis of the 3E PLUS tool by NAIMA (https://insulationinstitute.org/tools-resources/free-3e-plus/) yielded adjustment factors for horizontal to vertical loss and savings values. See DHW_PipeInsulationCalcs_062121.xlsx for details of the analysis and comparisons.

[654] Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

[655] Kits installation rate for DHW pipe insulation is from 2020 survey research by Guidehouse, conducted with Peoples Gas income qualified recipients of self install efficiency kits distributed by mail in late 2019. There were 117 survey respondents.

[656] An equal weighted average of Direct Install and Kit ISRs. Interest and applicability of measures confirmed through virtual assessment followed by self-installation without verification of install.

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

Type and Size	C_{Inside}[658] (I.D.*π/12) (ft)	Product of Overall Heat Transfer Coefficient and Pipe Area (UA) per foot[659] from bare pipe (BTU/hr·ft·°F)	Pipe Area per linear foot (ft^3)[660]	R_{exist} ((hr·ft·°F)/BTU)	Horizontal to Vertical Adjustment Factor (α)
½" Copper Pipe	0.1427	0.345	0.153	0.444	0.67
¾" Copper Pipe	0.2055	0.417	0.217	0.521	0.72
½" PEX	0.1270	0.438	0.145	0.332	0.73
¾" PEX	0.1783	0.545	0.204	0.374	0.77

For example, insulating 6 feet of 0.75" copper pipe (4ft vertical + 2ft horizontal) with R-5 wrap through a Direct Install program:

ΔkWh = (((1 / R_{exist} – 1 / R_{new}) * C_{inside} * $L_{effective}$ * ΔT * 8,766 * 1.0) / ηDHW) / 3412

= (((1/0.521 - 1/3.521) * 0.2055 * (2 + 4 * 0.72) * 60 * 8766 * 1.0) / 0.98)/3412

= 258 kWh

The following table provides annual energy savings per foot of pipe insulation for various configurations:

	ΔkWh Savings per Foot of Insulation (kWh/ft)	
Measure Configuration	**Kit Distribution (ISR = 56%)**	**All Other Programs (ISR = 100%)**
Horizontal Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	24.7	44.0
¾" Copper Pipe insulated with R-3, ½" thick insulation	29.6	52.9
½" PEX insulated with R-3, ½" thick insulation	30.3	54.2
¾" PEX insulated with R-3, ½" thick insulation	37.3	66.7
Vertical Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	16.5	29.5
¾" Copper Pipe insulated with R-3, ½" thick insulation	21.3	38.1
½" PEX insulated with R-3, ½" thick insulation	22.1	39.5
¾" PEX insulated with R-3, ½" thick insulation	28.8	51.3
Unknown		
R-3, ½" thick insulation for ½" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	23.4	41.8
R-3, ½" thick insulation for ¾" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	29.25	52.25
Unknown pipe type (straight average) and configuration	26.3	47.0

658 See: https://energy-models.com/pipe-sizing-charts-tables (last accessed 5/7/21) for copper pipe sizes and https://www.garagesanctum.com/size-chart/pex-tubing-size-chart/ (last accessed 5/7/21) for PEX pipe sizes.

659 Laboratory measured values from Hoeschele and Weitzel (2012), Figure 1.

660 Calculated using the average pipe thickness (I.D. + O.D.)*0.5.

	ΔkWh Savings per Foot of Insulation (kWh/ft)	
Measure Configuration	Kit Distribution (ISR = 56%)	All Other Programs (ISR = 100%)
(assume 3 ft vertical and remaining horizontal) insulated with R-3, ½" thick insulation		

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / 8766

Where:

ΔkWh = kWh savings from pipe wrap installation

8766 = Number of hours in a year (since savings are assumed to be constant over year).

For example, insulating 6 feet of 0.75" copper pipe (4ft vertical + 2ft horizontal) with R-5 wrap through a Direct Install program:

ΔkW = 258/8766

= 0.0294kW

The following table provides peak demand savings per foot of pipe insulation for various configurations:

	ΔkW Savings per Foot of Insulation (kW/ft)	
Measure Configuration	Kit Distribution (ISR = 56%)	All Other Programs (ISR = 100%)
Horizontal Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	0.0028	0.0050
¾" Copper Pipe insulated with R-3, ½" thick insulation	0.0034	0.0060
½" PEX insulated with R-3, ½" thick insulation	0.0035	0.0062
¾" PEX insulated with R-3, ½" thick insulation	0.0043	0.0076
Vertical Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	0.0019	0.0034
¾" Copper Pipe insulated with R-3, ½" thick insulation	0.0024	0.0043
½" PEX insulated with R-3, ½" thick insulation	0.0025	0.0045
¾" PEX insulated with R-3, ½" thick insulation	0.0033	0.0059
Unknown		
R-3, ½" thick insulation for ½" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.0027	0.0048
R-3, ½" thick insulation for ¾" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.0033	0.0060
Unknown pipe type (straight average) and configuration	0.0030	0.0054

	ΔkW Savings per Foot of Insulation (kW/ft)	
Measure Configuration	Kit Distribution (ISR = 56%)	All Other Programs (ISR = 100%)
(assume 3 ft vertical and remaining horizontal) insulated with R-3, ½" thick insulation		

NATURAL GAS SAVINGS

For Natural Gas DHW systems:

$$\Delta Therm = (((1 / R_{exist} - 1 / R_{new}) * C_{inside} * L_{effective} * \Delta T * 8{,}766 * ISR) / \eta DHW) / 100{,}000$$

Where:

ηDHW = Recovery efficiency of gas hot water heater

= 0.78 [661]

Other variables as defined above

> **For example**, insulating 6 feet of 0.75" copper pipe (4ft vertical + 2ft horizontal) with R-5 wrap through a Direct Install program:
>
> $$\Delta Therm = (((1 / R_{exist} - 1 / R_{new}) * C_{inside} * L_{effective} * \Delta T * 8{,}766 * ISR) / \eta DHW) / 100{,}000$$
>
> = (((1/0.521 - 1/3.521) * 0.2055 * (2 + 4 * 0.72) * 60 * 8766 * 1.0) / 0.78 / 100,000
>
> = 11.06 therms

The following table provides Natural Gas savings per foot of pipe insulation for various configurations:

	ΔTherm Savings per Foot of Insulation (Therms/ft)	
Measure Configuration	Kit Distribution (ISR = 56%)	All Other Programs (ISR = 100%)
Horizontal Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	1.06	1.89
¾" Copper Pipe insulated with R-3, ½" thick insulation	1.27	2.27
½" PEX insulated with R-3, ½" thick insulation	1.30	2.32
¾" PEX insulated with R-3, ½" thick insulation	1.60	2.86
Vertical Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	0.71	1.26
¾" Copper Pipe insulated with R-3, ½" thick insulation	0.91	1.63
½" PEX insulated with R-3, ½" thick insulation	0.95	1.70
¾" PEX insulated with R-3, ½" thick insulation	1.23	2.20
Unknown		
R-3, ½" thick insulation for ½" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	1.01	1.79

[661] 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%

	ΔTherm Savings per Foot of Insulation (Therms/ft)	
Measure Configuration	Kit Distribution (ISR = 56%)	All Other Programs (ISR = 100%)
R-3, ½” thick insulation for ¾” pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	1.25	2.24
Unknown pipe type (straight average) and configuration (assume 3 ft vertical and remaining horizontal) insulated with R-3, ½” thick insulation	1.13	2.02

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-PINS-V05-220101

REVIEW DEADLINE: 1/1/2025

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. [662]

Water Heater Type	Water Heater Volume (gallons)	Draw Pattern	Minimum Uniform Energy Factor
Gas Storage	≤ 55	Medium	≥ 0.64
		High	≥ 0.68
	> 55	Medium	≥ 0.78
		High	≥ 0.80
Gas Instantaneous	All	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 as provided below:

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[663]
Residential Gas Storage Water Heaters ≤75,000 Btu/h	≤55 gallon tanks	Very small	UEF = 0.3456 – (0.0020 * Rated Storage Volume in Gallons)
		Low	UEF = 0.5982 – (0.0019 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.6483 – (0.0017 * Rated Storage Volume in Gallons)
		High	UEF = 0.6920 – (0.0013 * Rated Storage Volume in Gallons)
	>55 gallon and ≤100	Very small	UEF = 0.6470 – (0.0006 * Rated Storage Volume in Gallons)

662 ENERGY STAR Product Specification for Residential Water Heaters, Version 4.0, effective April 5, 2021. Version 3 will be discontinued after January 5, 2022.
https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Water%20Heaters%20Final%20Specification%20and%20Partner%20Commitments_0.pdf

663 DOE Standard 10 CFR 430, Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431. Minimum Federal standard as of 4/16/2015, confirmed no changes as of 6/20/2021;
https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[663]
	gallon tanks	Low	UEF = 0.7689 – (0.0005 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.7897 – (0.0004 * Rated Storage Volume in Gallons)
		High	UEF = 0.8072 – (0.0003 * Rated Storage Volume in Gallons)

Draw patterns are based on first hour rating (gallons) for storage tanks as shown below:[664]

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

The same draw pattern (very small, low, medium and high draw) should be used for both baseline and efficient units. If using a deemed approach, for storage water heaters with a storage capacity equal to or less than 55 gallons, the Federal energy factor requirement is calculated as 0.6483 – (0.0017 * storage capacity in gallons) assuming a Medium draw and 0.8072 − (0.0003 × storage capacity in gallons) assuming a High draw for greater than 55 gallon storage water heaters.

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.[665]

For early replacement: Remaining life of existing equipment is assumed to be 4 years.[666]

DEEMED MEASURE COST

Time of Sale or New Construction:

The incremental capital cost for this measure is dependent on the type of water heater as listed below.[667]

Early Replacement: The full installed cost is provided in the table below. The assumed deferred cost (after 4 years) of replacing existing equipment with a new baseline unit is assumed to be $650.[668] 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

664 Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1
665 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.
666 Assumed to be one third of effective useful life
667 Source for cost info; DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14.
668 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%.

Water heater Type	Incremental Cost	Full Install Cost
Condensing gas storage	$685	$1299
Tankless whole-house unit	$605	$1219

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

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

Early replacement:[669]

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

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

ΔTherms for remaining measure life (next 7.3 years for gas storage unit and next 13.3 years for gas tankless unit):

$$= (1/ UEF_{BASE} - 1/UEF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0)/100{,}000$$

Where:

UEF_Baseline = Uniform Energy Factor rating of standard storage water heater according to federal standards[670] provided in table in baseline section and using the same draw pattern as the efficient equipment. For a deemed approach:

= For gas storage water heaters ≤55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

= For gas storage water heaters >55 gallons: 0.8072 − (0.0003 × storage capacity in gallons)

---

669 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).

670 Minimum Federal standard as of 4/16/2015, Confirmed no changes as of 6/23/2021.

= 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 unknown[671] assume,

= 0.64 for gas storage water heaters ≤55 gallons

= 0.78 for gas storage water heaters >55 gallons

= 0.87 for gas tankless water heaters.

UEF_Existing = Uniform Energy Factor rating for existing equipment

= Use actual UEF rating where it is possible to measure or reasonably estimate.

= if unknown assume 0.52 [672]

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household.[673]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[674]
Multifamily - Deemed	2.1[675]
Custom	Actual Occupancy or Number of Bedrooms[676]

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year, on average

γWater = Specific Weight of water

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= 125°F

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

= 50.7°F [677]

671 ENERGY STAR Product Specification for Residential Water Heaters, Version 4.0, effective April 5, 2021. Version 3 will be discontinued after January 5, 2022. Assuming medium draw pattern. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Water%20Heaters%20Final%20Specification%20and%20Partner%20Commitments_0.pdf

672 Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.

673 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

674 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

675 Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

676 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.

677 Table 4 in Chen, et. al., "Calculating Average Hot Water Mixes of Residential Plumbing Fixtures", June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.

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:

$$\Delta Therms = (1/0.58 - 1/0.80) * (17.6 * 2.56 * 365.25 * 8.33 * (125 - 50.7) * 1) / 100{,}000$$

$$= 48.3 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-GWHT-V10-220101

REVIEW DEADLINE: 1/1/2025

5.4.3 Heat Pump Water Heaters

DESCRIPTION

The installation of a heat pump domestic hot water heater in place of a standard electric water heater in a home. Savings are presented dependent on the heating system installed in the home due to the impact of the heat pump water heater on the heating loads.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an ENERGY STAR Heat Pump domestic water heater.[678]

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a new electric water heater meeting federal minimum efficiency standards,[679] dependent on the storage volume (in gallons) of the water heater.

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[680]
Residential Electric Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	Very small	UEF = 0.8808 – (0.0008 * Rated Storage Volume in Gallons)
		Low	UEF = 0.9254 – (0.0003 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.9307 – (0.0002 * Rated Storage Volume in Gallons)
		High	UEF = 0.9349 – (0.0001 * Rated Storage Volume in Gallons)
	>55 gallon and ≤120 gallon tanks [681]	Very small	UEF = 1.9236 – (0.0011 * Rated Storage Volume in Gallons)
		Low	UEF = 2.0440 – (0.0011 * Rated Storage Volume in Gallons)
		Medium	UEF = 2.1171 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 2.2418 – (0.0011 * Rated Storage Volume in Gallons)
Residential Electric Instantaneous Water Heaters	≤12kW and ≤2 gal	All other	UEF = 0.91
		High	UEF = 0.92

The same draw pattern (very small, low, medium and high draw) should be used for both baseline and efficient units. If using a deemed approach, for units ≤55 gallons – baseline is assumed to be a resistance storage unit with efficiency: 0.9307 – (0.0002 * rated volume in gallons) assuming medium draw.

For units >55 gallons – assume a 50 gallon resistance tank baseline;[682] i.e., 0.9299 UEF assuming high draw .

If unknown, assume a 50 gallon resistance tank baseline, at medium draw, therefore 0.9207 UEF.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[683]

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678 If the water heater does not have a UEF rating, but a EF rating, revert to using the previous version of this measure.
679 Minimum Federal Standard as of 4/1/2015, and updated in a Supplemental Notice of Proposed Rulemaking in 2016 assuming medium draw pattern.
680 All Residential sized Federal Standards are from DOE Standard 10 CFR 430, Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431.
681 It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline.
682 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.
683 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers.[684] See section below for detail.

DEEMED MEASURE COST

For Time of Sale or New Construction the incremental installation cost (including labor) should be used. Defaults are provided below.[685] 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
	≥2.6 UEF	$1,319	$3,116	$1,797

LOADSHAPE

Loadshape R18 - Residential Heat Pump Water Heater

COINCIDENCE FACTOR

The summer Peak Coincidence Factor is assumed to be 12%.[686]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = (((1/UEF_{BASE} - 1/UEF_{EFFICIENT}) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) + kWh\_cooling - kWh\_heating + Deh\_Reduction$

Where:

UEF_{BASE} = Uniform Energy Factor (efficiency) of standard electric water heater according to federal standards provided in table in baseline section and using the same draw pattern as the efficient equipment. For a deemed approach:

For <=55 gallons: 0.9307 – (0.0002 * rated volume in gallons)

For >55 gallons: Use 0.9299 [687]

[684] 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.

[685] 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.

[686] 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

[687] Assuming a 50 gallon tank baseline at High Draw due to the accommodate the higher gallon range. 50 gallon is the most common size for HPWHs.

= If unknown volume, use 0.9207 [688]

$UEF_{EFFICIENT}$ = Uniform Energy Factor (efficiency) of Heat Pump water heater

= Actual

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household [689]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[690]
Multifamily - Deemed	2.1[691]
Custom	Actual Occupancy or Number of Bedrooms[692]

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= 125°F

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

= 50.7°F [693]

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

3412 = Conversion from Btu to kWh

kWh_cooling[694] = Cooling savings from conversion of heat in home to water heat

$$=(((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) / 3412) – ((1/ UEF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) / 3412)) * LF * 27\%) / COP_{COOL}) * LM$$

Where:

[688] Assuming a 50 gallon tank baseline at Medium Draw.

[689] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[690] 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

[691] Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

[692] 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.

[693] Table 4 in Chen, et. al., "Calculating Average Hot Water Mixes of Residential Plumbing Fixtures", June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.

[694] 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.

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.22 for HPWH installation in an unknown location[695]

= 0.0 for installation in an unconditioned space

27% = Portion of reduced waste heat that results in cooling savings[696]

COP_{COOL} = COP of central air conditioning

= Actual, if unknown, assume 2.8 [697]

LM = Latent multiplier to account for latent cooling demand

= 1.33 [698]

kWh_heating = Heating cost from conversion of heat in home to water heat (dependent on heating fuel)

$= (((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) / 3412) –$

$((1/ UEF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) / 3412)) * LF * 5\%) / COP_{HEAT}) * (1 - \%NaturalGas)$

Where:

5% = Portion of reduced waste heat that results in increased heating load[699]

COP_{HEAT} = COP of electric heating system

= actual. If not available use:[700]

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

695 West Hills Energy and Computing (2019) found 78% of HPWHs “are installed in basements that are not intentionally heated.”
696 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).
697 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.
698 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.
699 The operation of a HPWH causes both sensible and latent heat transfer with the surrounding air (and water vapor). The amount of sensible heat transfer is governed by the specific heat capacity of water: 4,186 J/kg·°C (which is 4x larger than that of dry air) and the temperature change. The latent heat transfer is governed by the latent heat of vaporation for water: $22.6x10^5$ J/kg. Only the sensible heat transfer increases the heating load, and because of the relative sizes of these parameters, the latent heat transfer is several orders of magnitude greater than the sensible heat transfer. See HPWH_CalculationSheet.xlsx for the specific example used to derive the 5% portion for sensible heat.
700 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	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Unknown[701]	N/A	N/A	1.28

Deh_Reduction = Savings resulting from reduced dehumidification

= values based on table below[702]

Dehumidifcation Status	Deh_Reduction (kWh)
If Dehumidifer is in use	359
If unknown	72

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 in Belleville and dehumidifier usage is unknown:

ΔkWh = [(1 / 0.9207 – 1 / 2.0) * 17.6 * 2.56 * 365.25* 8.33 * (125 – 50.7) * 1.0] / 3412 + 188.9 – 0 + 72

= 2011 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / Hours * CF

Where:

Hours = Full load hours of water heater

= 2533 [703]

CF = Summer Peak Coincidence Factor for measure

= 0.12 [704]

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 and dehumidifier usage is unknown:

kW = 2010 / 2533 * 0.12

= 0.095kW

NATURAL GAS SAVINGS

ΔTherms = - (((((GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) – (GPD * Household

701 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.

702 West Hills Energy and Computing (2019) found that 20% of homes had dehumidifiers in use and in interviews with homeowners found the following reductions in dehumidifier usage: 46% reported “1 month or more reduction”, 32% reported “3 months or more reduction”, and 15% reported removal of a dehumidifier. kWh savings assumptions are based on an average of: Federal Standard, ENERGY STAR, and ENERGY STAR Most Efficient annual energy usage. See HPWH_CalculationSheet.xlsx for calculations.

703 Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

704 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

* 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) / $UEF_{EFFICIENT}$)) * LF * 5% * 0.03412) / ηHeat) * %NaturalGas

Where:

ΔTherms = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat [705]

0.03412 = conversion factor (therms per kWh)

ηHeat = Efficiency of heating system

= Actual.[706] If not available use 70%.[707]

%NaturalGas = Factor dependent on heating fuel:

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[708], use the following table:

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

Other factors as defined above

[705] 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.

[706] 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.

[707] 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

[708] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

For example, a 2.0 COP heat pump water heater in conditioned space, in a single family home with gas space heat (70% system efficiency):

ΔTherms = -(((((17.6 * 2.56 * 365.25* 8.33 * (125 – 50.7) * 1.0) / 3412) – (17.6 * 2.56 * 365.25* 8.33 * (125 – 50.7) * 1.0 / 3412 / 2.0)) * 1 * 0.05 * 0.03412) / 0.7) * 1

= - 3.6 therms

Mid-Life adjustment

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

Efficiency Assumption	System Type	New Baseline Efficiency
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER
ηHeat	Electric Resistance	1.0 COP
	Heat Pump (8.2HSPF/3.413)*0.85	2.04 COP
	Furnace 80% AFUE * 0.85	68% AFUE
	Boiler	84% 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.[709] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-HPWH-V11-220101

REVIEW DEADLINE: 1/1/2024

709 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.[710]

DEEMED MEASURE COST

For time of sale or new construction the incremental cost for this measure is $3,[711] or program actual.

For faucet aerators provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown, assume $8 for Direct Install[712] 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%.[713]

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[710] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[711] 2011, Market research average of $3.

[712] Includes assess and install labor time of $5 (20min @ $15/hr)

[713] 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[714] (unless faucet type is unknown, then it is per household).

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%[715]

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used."

= If unknown assume values in table below, or custom based on metering studies,[716] or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[717]

Note, if GPM_base is based upon the deemed assumptions below, since these include participants that had existing low flow fixtures, the freerider rate for this measure should be 0.

Faucet Type	GPM[718]
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"

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714 This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.

715 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

716 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.

717 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

718 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,[719] or custom based on metering studies,[720] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[721]

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[722]
Bathroom	1.6[723]
If faucet location unknown (total for household): Single-Family except mobile homes	9.0[724]
If location unknown (total for household): Multifamily and mobile homes	6.9[725]
If faucet location and building type unknown (total for household)	8.3[726]

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[727]
Bathroom	1.6[728]
If faucet location unknown (total for household): Single-Family except mobile homes	9.0[729]
If faucet location unknown (total for household):	6.9[730]

[719] 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.

[720] 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.

[721] 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.

[722] 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.

[723] Ibid.

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

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

[726] 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.

[727] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[728] Ibid.

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

[730] 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[731]

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[732]
Multi-Family - Deemed	2.1[733]
Household type unknown	2.42[734]
Custom	Actual Occupancy or Number of Bedrooms[735]

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[736]
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[737]
Bathroom Faucets Per Home (BFPH): Multifamily and mobile homes	1.5[738]
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

[731] 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.
[732] 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
[733] Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.
[734] 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.
[735] 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.
[736] 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.
[737] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
[738] Ibid.

Faucet Type	FPH
If faucet location and building type unknown (total for household)	3.42[739]

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

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (86 – 50.7)) / (0.98 * 3412)

= 0.0879 kWh/gal (Bath), 0.1054 kWh/gal (Kitchen), 0.1004 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[740]

SupplyTemp = Assumed temperature of water entering house

= 50.7°F [741]

RE_electric = Recovery efficiency of electric water heater

= 98% [742]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below

[739] 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.

[740] 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.

[741] Table 4 in Chen, et. al., "Calculating Average Hot Water Mixes of Residential Plumbing Fixtures", June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.

[742] Electric water heaters have recovery efficiency of 98%.http://www.ahridirectory.org/ahridirectory/pages/home.aspx

Selection	ISR
Direct Install - Single Family	0.95[743]
Direct Install –Multifamily Kitchen	0.91[744]
Direct Install –Multifamily Bathroom	0.95[745]
SF Virtual Assessment followed by Unverified Self-Install Bathroom Aerator	0.78[746]
SF Virtual Assessment followed by Unverified Self-Install Kitchen Aerator	0.765[747]
MF Virtual Assessment followed by Unverified Self-Install Bathroom Aerator	0.78[748]
Virtual Assessment followed by Unverified Self-Install Kitchen Aerator	0.745[749]
Requested Efficiency Kit Bathroom Aerator	0.61[750]
Requested Efficiency Kit Kitchen Aerator	0.58[751]
Distributed Efficiency Kit Bathroom Aerator (Income Eligible)	0.57[752]
Distributed Efficiency Kit Kitchen Aerator (Income Eligible)	0.55[753]
Community Distributed Kit Aerators	0.45[754]
Distributed School Efficiency Kit Bathroom Aerator	0.27[755]
Distributed School Efficiency Kit Kitchen Aerator	0.27[756]

Use Multifamily if: Building meets utility's definition for multifamily

743 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

744 Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report DRAFT 2013-01-28

745 Ibid.

746 An equal weighted average of Direct Install and Efficiency Kit ISRs. Guidehouse, *In-Service Rates for CY2020 Single Family Virtual Assessment Measures*, August 20, 2020. Interest and applicability of measures confirmed through virtual assessment. Please note, these ISRs do not apply to retail purchases by end user.

747 Ibid.

748 An equal weighted average of Direct Install and Efficiency Kit ISRs. Interest and applicability of measures confirmed through virtual assessment. Please note, these ISRs do not apply to retail purchases by end user.

749 Ibid.

750 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.

751 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.

752 Guidehouse survey research for Peoples Gas, June 16, 2020.

753 Guidehouse survey research for Peoples Gas, June 16, 2020.

754 Research from 2018 Ameren Illinois Income Qualified participant survey.

755 Opinion Dynamics and Cadmus. 2018 AIC Residential Program Annual Impact Evaluation Report. April 30, 2019. Results from implementer-administered participant survey.

756 Ibid

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

$$\Delta kWh = 1.0 * (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.1054 * 0.95$$
$$= 218.0 \text{ kWh}$$

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

$$\Delta kWh = 1.0 * (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.0879 * 0.95$$
$$= 36.3 \text{ kWh}$$

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

$$\Delta kWh = 1.0 * (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.1004 * 0.95$$
$$= 106.6 \text{ kWh}$$

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.

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

Where

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

=5010[757]

For example, a direct installed kitchen low flow aerator in an single family home

$$\Delta Water\ (gallons) = (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.95$$
$$= 2068 \text{ gallons}$$
$$\Delta kWh_{water} = 2068/1000000 * 5010$$
$$=10.4 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

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

= ((GPM_base * L_base) * Household/FPH * 365.25 * DF) * 0.567[758] / GPH

Building Type	Faucet location	Calculation	Hours per faucet
Single Family	Kitchen	((1.63 * 4.5) * 2.56/1 * 365.25 * 0.75) * 0.567 / 26.1	112
	Bathroom	((1. 53 * 1.6) * 2.56/2.83 * 365.25 * 0.9) * 0.567 / 26.1	16
	Unknown	((1. 58* 9.0) * 2.56/3.83 * 365.25 * 0.795) * 0.567 / 26.1	60
Multifamily	Kitchen	((1. 63 * 4.5) * 2.1/1 * 365.25 * 0.75) * 0.567 / 26.1	92

757 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'.

758 56.7% is the proportion of hot 120F water mixed with 50.7F supply water to give 90F mixed faucet water.

	Bathroom	((1. 53* 1.6) * 2.1/1.5 * 365.25 * 0.9) * 0.567 / 26.1	24
	Unknown	((1. 58 * 6.9) * 2.1/2.5 * 365.25 * 0.795) * 0.567 / 26.1	58

GPH = Gallons per hour recovery of electric water heater calculated for 69.3F temp rise (120-50.7), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 26.1

CF = Coincidence Factor for electric load reduction

= 0.022[759]

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

ΔkW =182/112 * 0.022

= 0.036 kW

NATURAL GAS SAVINGS

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[760]

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.0038 Therm/gal for SF homes (Bath), 0.0045 Therm/gal for SF homes (Kitchen), 0.0043 Therm/gal for SF homes (Unknown)

= 0.0044 Therm/gal for MF homes (Bath), 0.0053 Therm/gal for MF homes (Kitchen), 0.0050 Therm/gal for MF homes (Unknown)

RE_gas = Recovery efficiency of gas water heater

= 78% For individual water heater[761]

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759 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

760 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

761 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%.

= 67% For shared water heater[762]

If unknown, use individual water heater value for single family, use shared water heater value for multifamily. Use multifamily if building meets utility's definition for multifamily.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

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

ΔTherms = 1.0 * (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.0045 * 0.95

= 9.31 Therms

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

ΔTherms = 1.0 * (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.0044 * 0.95

= 1.82 Therms

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

ΔTherms = 1.0 * (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.0043 * 0.95

= 4.57 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * ISR

Variables as defined above

For example, a direct-installed kitchen low flow aerator in a single family home

ΔWater (gallons) = (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.95

= 2068 gallons

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

ΔWater (gallons) = (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.95

= 413 gallons

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

ΔWater (gallons) = (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.95

= 1062 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

762 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.

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-V11-220101

REVIEW DEADLINE: 1/1/2024

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.[763]

DEEMED MEASURE COST

For time of sale or new construction the incremental cost for this measure is $7 or program actual.[764]

For low flow showerheads provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $12 for Direct Install[765] 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%.[766]

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763 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.
764 Market research average of $7.
765 Includes assess and install labor time of $5 (20min @ $15/hr)
766 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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%[767]

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used."

Note, if GPM_base is based upon the deemed assumptions below, since these include participants that had existing low flow fixtures, the freerider rate for this measure should be 0.

Program	GPM_base
Direct-install	2.24[768]
Retrofit, Efficiency Kits, NC or TOS	2.35[769]

GPM_low = As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaulations deviate from rated flows, see table below:

Rated Flow
2.0 GPM
1.75 GPM
1.5 GPM
Custom or Actual[770]

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

767 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

768 Based on measurements conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

769 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.

770 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.

L_base = Shower length in minutes with baseline showerhead

= 7.8 min[771]

L_low = Shower length in minutes with low-flow showerhead

= 7.8 min[772]

Household = Average number of people per household

Household Unit Type[773]	Household
Single-Family - Deemed	2.56[774]
Multi-Family - Deemed	2.1[775]
Household type unknown	2.42[776]
Custom	Actual Occupancy or Number of Bedrooms[777]

Use Multifamily if: Building meets utility's definition for multifamily

SPCD = Showers Per Capita Per Day

= 0.6[778]

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[779]
Multifamily and mobile homes	1.3[780]
Household type unknown	1.64[781]
Custom	Actual

Use Multifamily if: Building meets utility's definition for multifamily

EPG_electric = Energy per gallon of hot water supplied by electric

771 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.

772 Ibid.

773 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

774 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

775 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

776 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.

777 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.

778 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

779 Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

780 Ibid.

781 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.

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 50.7)) / (0.98 * 3412)

= 0.125 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[782]

SupplyTemp = Assumed temperature of water entering house

= 50.7°F [783]

RE_electric = Recovery efficiency of electric water heater

= 98%[784]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependant on program delivery method as listed in table below

[782] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[783] Table 4 in Chen, et. al., “Calculating Average Hot Water Mixes of Residential Plumbing Fixtures”, June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.

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

Selection	ISR
Direct Install - Single Family	0.97[785]
Direct Install –Multifamily	0.95[786]
SF Virtual Assessment followed by Unverified Self-Install One Showerhead	0.795[787]
SF Virtual Assessment followed by Unverified Self-Install Two Showerheads	0.82[788]
MF Virtual Assessment followed by Unverified Self-Install One Showerhead	0.785[789]
MF Virtual Assessment followed by Unverified Self-Install Two Showerheads	0.81[790]
Requested Efficiency Kits--One showerhead kit	0.62[791]
Requested Efficiency Kits—Two showerhead kit	0.67[792]
Distributed Efficiency Kits--One showerhead kit (Income Eligible)	0.57[793]
Distributed School Efficiency Kit showerhead	0.25[794]

Use Multifamily if: Building meets utility's definition for multifamily

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

$$\Delta kWh = 1.0 * ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.125 * 0.97$$

$$= 219 \text{ kWh}$$

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

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

Where

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

= 5010[795]

785 Weighted average of 98% found in 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 (quantity surveyed = 163), and 87% from ComEd Single Family Retrofits CY2018 Field Work Memo 2019-07-19, Table 1 (quantity surveyed = 15). Alternative ISRs may be developed for program delivery methods based on evaluation results.

786 Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report FINAL 2013-06-05

787 An equal weighted average of Direct Install and Efficiency Kit ISRs. Interest and applicability of measures confirmed through virtual assessment.

788 Ibid.

789 An equal weighted average of Direct Install and Efficiency Kit ISRs. Interest and applicability of measures confirmed through virtual assessment.

790 Ibid.

791 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.

792 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.

793 Guidehouse survey research for Peoples Gas, June 16, 2020.

794 Opinion Dynamics and Cadmus. 2018 AIC Residential Program Annual Impact Evaluation Report. April 30, 2019. Results from implementer-administered participant survey.

795 This factor includes 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and

> **For example**, a direct installed 1.5 GPM low flow showerhead in a single family where the number of showers is not known:
>
> ΔWater (gallons) = ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.97
>
> = 1756 gallons
>
> ΔkWh_{water} = 1773/1,000,000 * 5010
>
> = 8.9 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

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

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) * Household * SPCD * 365.25) * 0.726[796] / GPH

= 273 for SF Direct Install; 224 for MF Direct Install

= 286 for SF Retrofit, Efficiency Kits, NC and TOS; 236 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 69.3F temp rise (120-50.7), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 26.1

CF = Coincidence Factor for electric load reduction

= 0.0278[797]

> **For example**, a direct installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:
>
> ΔkW = 219/273 * 0.0278
>
> = 0.022 kW

NATURAL GAS SAVINGS

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

---

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'.

[796] 72.6% is the proportion of hot 120F water mixed with 50.7F supply water to give 101F shower water.

[797] 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	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[798]

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.0054 Therm/gal for SF homes

= 0.0063 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For individual water heater[799]

= 67% For shared water heater[800]

If unknown, use individual water heater value for single family, use shared water heater value for multifamily. Use multifamily if building meets utility's definition for multifamily.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

> **For example**, a direct installed 1.5 GPM low flow showerhead in a gas fired DHW single family home where the number of showers is not known:
>
> ΔTherms = 1.0 * ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.0054 * 0.97
>
> = 9.5 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

> **For example**, a direct installed 1.5 GPM low flow showerhead in a single family home where the number of showers is not known:
>
> ΔWater (gallons) = ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.97
>
> = 1754 gallons

798 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

799 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%.

800 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.

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-V10-220101

REVIEW DEADLINE: 1/1/2024

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 where the measure is installed as part of a kit program, the cost of the informational insert or other product should be used.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 1.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For homes with electric DHW tanks:

ΔkWh[801]= (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)

Where:

U = Overall heat transfer coefficient of tank (Btu/Hr-°F-ft^2).

= Actual if known. If unknown assume R-12, U = 0.083

A = Surface area of storage tank (square feet)

[801] Note this algorithm provides savings only from reduction in standby losses. The TAC considered avoided energy from not heating the water to the higher temperature but determined that dishwashers are likely to boost the temperature within the unit (roughly canceling out any savings), faucet and shower use is likely to be at the same temperature so there would need to be more lower temperature hot water being used (cancelling any savings) and clothes washers will only see savings if the water from the tank is taken without any temperature control. It was felt the potential impact was too small to be characterized.

= Actual if known. If unknown use table below based on capacity of tank. If capacity unknown assume 50 gal tank; A = 24.99ft^2

Capacity (gal)	A (ft^2)[802]
30	19.16
40	23.18
50	24.99
80	31.84

Tpre = Actual hot water setpoint prior to adjustment

Tpost = Actual new hot water setpoint, which may not be lower than 120 degrees

Default Hot Water Temperature Inputs	
Tpre	135
Tpost	120

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

ISR = In service rate of measure

= Dependent on program delivery method as listed in table below

Delivery method	ISR
Distributed school efficient kit instructions	13%[803]
Instructions provided in all other Kit programs	10%[804]
All other	100%

3412 = Conversion from Btu to kWh

RE_electric = Recovery efficiency of electric hot water heater

= 0.98 [805]

A deemed savings assumption for non-kit programs, where site specific assumptions are not available would be as follows:

[802] 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.
[803] Opinion Dynamics and Cadmus. 2018 AIC Residential Program Annual Impact Evaluation Report. April 30, 2019. Results from implementer-administered participant survey.
[804] Opinion Dynamics. Impact and Process Evaluation of 2014 (PY7) Illinois Power Agency Rural Kits Program. April 19, 2016.
[805] Electric water heaters have recovery efficiency of 98%.

ΔkWh = (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (3412 * 0.98)

= 81.6 kWh

For school kit programs, the default savings is 10.6 kWh and for all other kit programs the default savings is 8.2 kWh.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW **=** ΔkWh / Hours * CF

Where:

Hours = 8766

CF = Summer Peak Coincidence Factor for measure

= 1

A deemed savings assumption for non-kit programs, where site specific assumptions are not available would be as follows:

ΔkW = (81.6/ 8766) * 1

ΔkW default = 0.0093 kW

For school kit programs, the default savings is 0.0012kW and for all other kit programs the default savings is 0.00094kW.

NATURAL GAS SAVINGS

For homes with gas water heaters:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (100,000 * RE_gas)

Where

100,000 = Converts Btus to Therms (btu/Therm)

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes [806]

= 67% For MF homes[807]

Use Multifamily if: Building has shared DHW

A deemed savings assumption for non-kit programs, where site specific assumptions are not available would be as follows:

For Single Family homes:

[806] 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%.

[807] 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.

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (RE_gas)

= ((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (100,000 * 0.78)

= 3.5 Therms

For school kit programs, the default savings is 0.45 Therms and for all other kit programs the default savings is 0.35 Therms.

For Multi Family homes:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (RE_gas)

= ((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (100,000 * 0.67)

= 4.1 Therms

For school kit programs, the default savings is 0.53 Therms and for all other kit programs the default savings is 0.41 Therms.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-TMPS-V08-210101

REVIEW DEADLINE: 1/1/2025

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.[808]

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The measure is a properly installed, R-8 or greater insulating tank wrap to reduce standby energy losses from the tank to the surrounding ambient area.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a standard electric domestic hot water tank without an additional tank wrap. Gas storage water heaters are excluded due to the limitations of retrofit wrapping and the associated impacts on reduced savings and safety.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 5 years.[809]

DEEMED MEASURE COST

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

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For electric DHW systems:

$$\Delta kWh = ((1/ Rbase – 1 / R_{insul}) * A_{base} * \Delta T * Hours) / (3412 * \eta DHW)$$

Where:

[808] Visually determine whether it is insulated by foam (newer, rigid, and more effective) or fiberglass (older, gives to gently pressure, and not as effective)
[809] This estimate assumes the tank wrap is installed on an existing unit with 5 years remaining life.

R_{base} = Overall thermal resistance coefficient prior to adding tank wrap (Hr-°F-ft²/BTU).

R_{insul} = Overall thermal resistance coefficient after addition of tank wrap (Hr-°F-ft²/BTU).

A_{base} = Surface area of storage tank prior to adding tank wrap (square feet)[810]

ΔT = Average temperature difference between tank water and outside air temperature (°F)

= 60°F [811]

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

3412 = Conversion from Btu to kWh

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [812]

The following table has default savings for various tank capacity and pre and post R-VALUES.

Capacity (gal)	Rbase	Rinsul	Abase (ft2)[813]	ΔkWh	ΔkW
30	8	16	19.16	188	0.0215
30	10	18	19.16	134	0.0153
30	12	20	19.16	100	0.0115
30	8	18	19.16	209	0.0239
30	10	20	19.16	151	0.0172
30	12	22	19.16	114	0.0130
40	8	16	23.18	228	0.0260
40	10	18	23.18	162	0.0185
40	12	20	23.18	122	0.0139
40	8	18	23.18	253	0.0289
40	10	20	23.18	182	0.0208
40	12	22	23.18	138	0.0158
50	8	16	24.99	246	0.0280
50	10	18	24.99	175	0.0199
50	12	20	24.99	131	0.0149
50	8	18	24.99	273	0.0311
50	10	20	24.99	197	0.0224
50	12	22	24.99	149	0.0170
80	8	16	31.84	313	0.0357
80	10	18	31.84	223	0.0254
80	12	20	31.84	167	0.0190
80	8	18	31.84	348	0.0397
80	10	20	31.84	250	0.0286
80	12	22	31.84	190	0.0216

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW **=** ΔkWh / 8766 * CF

[810] Area includes tank sides and top to account for typical wrap coverage.
[811] Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.
[812] Electric water heaters have recovery efficiency of 98%.
[813] 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.

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-V03-220101

REVIEW DEADLINE: 1/1/2026

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.[814]

DEEMED MEASURE COST

The incremental cost of the measure should be the actual program cost (including labor if applicable), or $30[815] plus $20 labor[816] if not available.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.22%.[817]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) *

[814] Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead.
[815] Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.
[816] Estimate for contractor installation time.
[817] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022

EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%[818]

GPM_base_S = Flow rate of the basecase showerhead, or actual if available

Program	GPM
Direct-install, device only	2.24[819]
New Construction or direct install of device and low flow showerhead	Rated or actual flow of program-installed showerhead
Retrofit or TOS	2.35[820]

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

= 0.89 minutes[821]

Household = Average number of people per household

Household Unit Type[822]	Household
Single-Family - Deemed	2.56[823]
Multi-Family - Deemed	2.1[824]
Household type unknown	2.42[825]
Custom	Actual Occupancy or Number of Bedrooms[826]

Use Multifamily if: Building meets utility's definition for multifamily

SPCD = Showers Per Capita Per Day

818 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

819 Based on measurements conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

820 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.

821 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.

822 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

823 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

824 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

825 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.

826 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[827]

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[828]
Multifamily	1.3[829]
Household type unknown	1.64[830]
Custom	Actual

Use Multifamily if: Building meets utility's definition for multifamily

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 50.7)) / (0.98 * 3412)

= 0.125 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

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

ShowerTemp = Assumed temperature of water

= 101F [831]

SupplyTemp = Assumed temperature of water entering house

= 50.7°F [832]

RE_electric = Recovery efficiency of electric water heater

= 98% [833]

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[834]

[827] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[828] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
[829] Ibid.
[830] 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.
[831] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[832] Table 4 in Chen, et. al., "Calculating Average Hot Water Mixes of Residential Plumbing Fixtures", June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.
[833] Electric water heaters have recovery efficiency of 98%.
[834] 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[835]
Efficiency Kits	To be determined through evaluation

Use Multifamily if: Building meets utility's definition for multifamily

For example, a direct installed valve in a single-family home with electric DHW:

ΔkWh = 1.0 * (2.24 * 0.89 * 2.56 * 0.6 * 365.25 / 1.79) * 0.125 * 0.98

= 76.5 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

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

Where

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

=5,010[836]

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

ΔWater (gallons) = ((2.24* 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98

= 612 gallons

ΔkWh_{water} = 612/1,000,000 * 5010

= 3.1 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

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

Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device

= ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25) * 0.726[837] / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 69.3F temp rise (120-50.7), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 26.1

= 31.1 for SF Direct Install; 25.5 for MF Direct Install

[835] Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report FINAL 2013-06-05

[836] 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'.

[837] 72.6% is the proportion of hot 120F water mixed with 50.7F supply water to give 101F shower water.

= 32.6 for SF Retrofit and TOS; 26.7 for MF Retrofit and TOS

Use Multifamily if: Building meets utility's definition for multifamily

CF = Coincidence Factor for electric load reduction

= 0.0022[838]

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

ΔkW = 76.5/31.1 * 0.0022

= 0.0054 kW

NATURAL GAS SAVINGS

ΔTherms = %FossilDHW * ((GPM_base_S * L_showerdevice)* Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[839]

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.0054 Therm/gal for SF homes

= 0.0063 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[840]

= 67% For MF homes[841]

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838 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

839 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

840 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%.

841 Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery

Use Multifamily if: Building has shared DHW.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

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

ΔTherms = 1.0 * ((2.24 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.0054 * 0.98

= 3.3 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

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

ΔWater (gallons) = ((2.24 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98

= 612 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 &

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.

Source ID	Reference
	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-V06-220101

REVIEW DEADLINE: 1/1/2023

5.4.9 Shower Timer

DESCRIPTION

Shower Timers are designed to make it easy for people to consistently take short showers, resulting in water and energy savings.

The shower timer provides a reminder to participants on length of their shower visually or auditorily.

This measure was developed to be applicable to the following program type: KITS, DI.

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

DEFINITION OF EFFICIENT EQUIPMENT

The shower timer should provide a reminder to participants to keep showers to a length of 5 minutes or less.

DEFINITION OF BASELINE EQUIPMENT

The baseline is no shower timer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime is 2 years.[842]

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%.[843]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = %Electric DHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Electric

Where:

%Electric DHW = Proportion of water heating supplied by electric resistance heating

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842 Estimate of persistence of behavior change instigated by the shower timer.

843 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%[844]

GPM = Flow rate of showerhead as used

= Custom, to be determined through evaluation. If data is not available use 1.93[845]

L_base = Number of minutes in shower without a shower timer

=7.8 minutes[846]

L_timer = Number of minutes in shower after shower timer

= Custom, to be determined through evaluation. If data is not available use 5.79.[847]

Household = Number in household using timer

Household Unit Type[848]	Household
Single-Family - Deemed	2.56[849]
Multi-Family - Deemed	2.1[850]
Household type unknown	2.42[851]
Custom	Actual Occupancy or Number of Bedrooms[852]

Days/yr = 365.25

SPCD = Showers Per Capita Per Day

= 0.6[853]

UsageFactor = How often each participant is using shower timer

=Custom, to be determined through evaluation. If data is not available use 0.34[854]

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844 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

845 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

846 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.

847 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

848 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

849 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

850 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

851 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.

852 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.

853 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

854 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

EPG_Electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 50.7)) / (0.98 * 3412)

=0.125 kWh/gal

Where:

ShowerTemp = Assumed temperature of water

= 101°F[855]

SupplyTemp = Assumed temperature of water entering house

= 50.7°F [856]

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

ΔkWh = %Electric DHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Electric

= 0.16 * 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.125

=14.8kWh

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.

ΔkWh_{water} = ΔWater (gallons) / 1,000,000 * $E_{water\ total}$

Where

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

=5,010[857]

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

ΔWater (gallons) = GPM * (L_base – L_timer) * Household ***** Days/yr * SPCD * UsageFactor

= 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34

= 740.0 gallons

ΔkWh_{water} = 740/1,000,000 * 5010

= 3.7 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

[855] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[856] Table 4 in Chen, et. al., “Calculating Average Hot Water Mixes of Residential Plumbing Fixtures”, June 2020, reports a value of 50.7°F for inlet water temperature for U.S. Census Division 3.

[857] 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’.

Where:

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

Hours = Annual electric DHW recovery hours for showerhead use

= (GPM_base * L_base * Household * SPCD * UsageFactor * 365.25) * 0.726 [858] / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 69.3F temp rise (120-50.7), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 26.1

CF = Coincidence Factor for electric load reduction

= 0.0278[859]

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

Hours = (1.93 * 7.8 * 2.56 * 0.6 * 0.34 * 365.25) * 0.726/26.1

= 79.9 Hours

ΔkW = ΔkWh/Hours * CF

= 14.8 / 79.9 * 0.0278

= 0.0051 kW

NATURAL GAS SAVINGS

ΔTherms = %FossilDHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas

%FossilDHW = Proportion of water heating supplied by electric resistance heating

DHW fuel	%FossilDHW
Electric	0%
Natural Gas	100%
Unknown	84%[860]

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00537 Therm/gal for SF homes

= 0.00625 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

858 72.6% is the proportion of hot 120F water mixed with 50.7F supply water to give 101F shower water.

859 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

860 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

= 78% For SF homes [861]

= 67% For MF homes[862]

Use Multifamily if: Building has shared DHW.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

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

Δ Therms = %FossilDHW * GPM * (L_base – L_timer) * Household ***** Days/yr * SPCD * UsageFactor * EPG_Gas

= 0.84 * 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.00537

= 3.3 Therms

WATER DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = GPM * (L_base – L_timer) * Household ***** Days/yr * SPCD * UsageFactor

Variables as defined above

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

ΔWater (gallons) = GPM * (L_base – L_timer) * Household ***** Days/yr * SPCD * UsageFactor

= 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34

= 740.0 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-DHW-SHTM-V04-220101

REVIEW DEADLINE: 1/1/2026

[861] 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%.

[862] 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.

5.4.10 Pool Covers

DESCRIPTION

This measure refers to the installation of covers on residential use pools that are heated with gas-fired equipment located either indoors or outdoors. By installing pool covers, the heating load on the pool boiler will be reduced by reducing the heat loss from the water to the environment and the amount of actual water lost due to evaporation (which then requires additional heated water to make up for it). An additional benefit to pool covers are the electricity savings from the reduced fresh water required to replace the evaporated water.

The main source of energy loss in pools is through evaporation. This is particularly true of outdoor pools where wind plays a larger role. The point of installing pool covers is threefold. First, it will reduce convective losses due to the wind by shielding the water surface. Second, it will insulate the water from the colder surrounding air. And third, it will reduce radiative losses to the night sky. In doing so, evaporative losses will also be minimized, and the boiler will not need to work as hard in replenishing the pool with hot water to keep the desired temperature.

This measure can be used for pools that (1) currently do not have pool covers, (2) have pool covers that are past the useful life of the existing cover, or (3) have pool covers that are past their warranty period and have failed.

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

DEFINITION OF EFFICIENT EQUIPMENT

For indoor pools, the efficient case is the installation of an indoor pool cover with a 5 year warranty on an indoor pool that is used all year.

For outdoor pools, the efficient case is the installation of an outdoor pool cover with a 5 year warranty on an outdoor pool that is used through the summer season.

DEFINITION OF BASELINE EQUIPMENT

For indoor pools, the base case is an uncovered indoor pool that operates all year.

For outdoor pools, the base case is an outdoor pool that is uncovered and is open through the summer season.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The useful life of this measure is assumed to be 6 years.[863]

DEEMED MEASURE COST

The table below shows the costs for the various options and cover sizes. Since this measure covers a mix of various sizes, the average cost of these options is taken to be the incremental measure cost. [864] Costs are per square foot.

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[863] The effective useful life of a pool cover is typically one year longer than its warranty period. SolaPool Covers. Pool Covers Website, FAQ- "How long will my SolaPool cover blanket last?". Pool covers are typically offered with 3 and 5 year warranties with at least one company offering a 6 year warranty. Conversation with Trade Ally. Knorr Systems

[864] Pool Cover Costs: Lincoln Pool Equipment online catalog. Accessed 7/18/2019.

Cover Size	Edge Style	
	Hemmed (indoor)	Weighted (outdoor)
1-299 sq. ft.	$3.91	$4.08
300-999 sq. ft.	$2.61	$2.78
Average	$3.26	$3.43

LOADSHAPE

Loadshape R15 – Residential Pool Pumps

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

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

Where

$E_{water\ supply}$ = Water Supply Energy Factor (kWh/Million Gallons)

= 2,571[865]

[865] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'. Note since the water loss associated with this measure is due to evaporation and does not discharge into the wastewater system, only the water supply factor is used here.

For example**:**

For a 392 ft2 Indoor Swimming Pool:

ΔWater = WaterSavingFactor x Size of Pool

= 15.28 gal./ft2/year x 392 ft2

= 5,990 gal./year

ΔkWhwater = ΔWater / 1,000,000 * Ewater total

= 5,990 gal./year / 1,000,000 * 2,571 kWh/million gallons

= 15.4 kWh/year

For a 392 ft2 Outdoor Swimming Pool:

ΔWater = WaterSavingFactor x Size of Pool

= 8.94 gal./ft2/year x 392 ft2

= 3,504 gal./year

ΔkWhwater = ΔWater / 1,000,000 * $E_{water\ supply}$

= 3,504 gal./year / 1,000,000 * 2,571 kWh/million gallons

= 9.0 kWh/year

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

The calculations are based on modeling runs using RSPEC! Energy Smart Pools Software that was created by the U.S. Department of Energy. [866]

ΔTherms = SavingFactor x Size of Pool

Where

Savings factor = dependant on pool location and listed in table below:[867]

Location	Therm / sq-ft
Indoor	2.61
Outdoor	1.01

Size of Pool = Actual. If unknown assume 392 ft^2 [868]

WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = WaterSavingFactor x Size of Pool

Where

WaterSavingFactor = Water savings for this measure dependant on pool location and listed in table below:[869]

[866] Full method and supporting information found in reference document: IL TRM – Residential Pool Covers WorkPaper.docx. Note that the savings estimates are based upon Chicago weather data.

[867] Calculations can be found in Residential Pool Covers.xlsx

[868] The average size of an installed in-ground swimming poll is 14 ft x 28 ft, giving a surface area of 392 ft^2. <https://www.homeadvisor.com/cost/swimming-pools-hot-tubs-and-saunas/inground-pool/>

[869] Ibid.

Location	Annual Savings Gal / sq-ft
Indoor	15.28
Outdoor	8.94

Size of Pool = 392 ft^2

DEEMED O&M COST ADJUSTMENT CALCULATION

There are no O&M cost adjustments for this measure.

MEASURE CODE: RS-HWE-PLCV-V01-200101

REVIEW DEADLINE: 1/1/2024

5.4.11 Drain Water Heat Recovery

DESCRIPTION

Drain Water Heat Recovery (DWHR) is a technology that captures waste heat in the drain line during a shower event, using the reclaimed heat to preheat cold water that is then delivered either to the shower or the water heater. The device can be installed in either an equal flow configuration (with preheated water being routed to both the water heater and the shower) or an unequal flow configuration (preheated water directed to either the water heater or shower). The energy harvested from a DWHR device is maximized in an equal flow configuration. It uses a non-regenerative heat exchanger to pre-heat the incoming cold fresh water with the outgoing warm drain water. It has been proven that DWHR devices only recover energy during simultaneous draws,[870] i.e., showers, and that for energy savings purposes all other water draws can be ignored. Savings are calculated per drain water heat recovery unit. Other benefits include increased first-hour rating of water tank, improved comfort due to slower temperature degradation at run-out and reduction of coincident peak demand.[871]

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

DEFINITION OF EFFICIENT EQUIPMENT

Efficient equipment is a DWHR unit retrofitted to the main drain which includes outlets from showers, sinks and other fixtures too. Note, that the DWHR unit can either be installed in a vertical configuration or a horizontal configuration. Although, this measure covers both horizontal and vertical DWHR,[872] the energy savings calculations focuses on vertical. Due to the lack of any moving parts, no maintenance is required for either types of DWHR units. Vertical units are said to comprise 95% of the market currently.[873]

The device can be installed in either an equal flow configuration or an unequal flow configuration. A equal flow installation is ideal with all the incoming cold water passing through the DWHR heat exchanger apparatus, after which it splits into cold water and inlet to water heater. Units should be installed in single-family homes and multi-family homes.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a storage type water heater without DWHR devices in a residential application.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 30 years.[874]

DEEMED MEASURE COST

The incremental cost for this measure is $742 per unit.[875]

LOADSHAPE

Load Shape R03 – Residential Electric DHW

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[870] Charles Zaloum, John Gusdorf, and Anil Parekh; "Performance Evaluation of Drain Water Heat Recovery Technology at the Canadian Centre for Housing Technology", January 2007, accessed April 2020.
[871] G.Proskiw, "Technology Profile: Residential Greywater Heat Recovery Systems", June 1998, accessed April 2020.
[872] 2019 Title 24, Part 6 CASE Report. "Drain Water Heat Recovery – Final Report."
[873] Ibid
[874] Ibid
[875] Ibid

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 2.78%.[876]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For electric water heating, annual energy savings per unit are calculated through the following formula:

$$\Delta kWh = \frac{(ShowerTemp - SupplyTemp) \times 8.33\frac{BTU}{gal\cdot°F} \times GPM \times T_{shower-length} \times N_{persons} \times N_{units} \times \mathrm{SPCD} \times 365.25\frac{days}{yr} \times SF}{3412\frac{BTU}{kWh} \times RE}$$

Where:

ShowerTemp = assumed water temperature during shower

= 101°F[877]

SupplyTemp = assumed temperature of cold water entering house

= 50.7°F[878]

8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

GPM = gallon per minute, flow rate of showerhead

= 2.24 Gallon/minute for direct installed showerheads [879]

= 2.35 Gallon/minute for retrofit, efficiency kits, NC, or TOS[880]

$T_{shower-length}$ = shower length in minutes

= 7.8 minute[881]

$N_{persons}$ = average number of people per household

[876] Assume coincidence factor for DWHR units is the same with that of low flow showerheads (see 2020 Illinois Statewide Technical Reference Manual for Energy Efficiency, section 5.4.5, low flow showerheads)

[877] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[878] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

[879] Based on measurements conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

[880] 2020 Illinois Statewide Technical Reference Manual for Energy Efficiency, section 5.4.5, low flow showerheads

[881] 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.

Household Unit Type	Household
Single-Family - Deemed	2.56[882]
Multi-Family – Deemed	2.1[883]
Household type unknown	2.42[884]

N_{units} = Number of units in a multifamily building with drains connected to the DWHR unit

Household Unit	N_{units}
Single-Family	1
Multi-Family	1 or Actual

SPCD = Showers Per Capita Per Day

= 0.6[885]

365.25 = Days per year, on average.

SF = Water heating energy savings factor

= 0.4[886]

3,412 = Conversion factor, 1 kWh equals 3,412 BTU

RE = Recovery efficiency of electric water heater

= 0.98[887] or Actual

For example, for electric water heating, DHWR energy savings for a single family home can be calculated as follows:

ΔkWh = ((101 – 50.7) * 8.33 * 2.24 * 7.8 * 2.56 * 1 * 0.6 * 365.25 * 0.4) / (3412 * 0.98)

= 491.3 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value from above.

Hours = Annual electric DHW recovery hours for showerhead use

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882 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

883 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx (see 2020 Illinois Statewide Technical Reference Manual for Energy Efficiency, section 5.4.5, low flow showerheads)

884 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.

885 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

886 Federal Energy Management Program, <Heat Recovery from Wastewater Using a Gravity-Film Exchanger>, “based on our measurements, a 30 to 50% savings in the energy needed to heat shower water seems reasonable.” Here, we adopt an average of 40% as water heating energy savings factor;

887 Electric water heaters typically have recovery efficiency of 98%.

= ((GPM * $T_{shower-length}$) * $N_{persons}$ * SPCD * 365.25) * 0.726 [888]/ GPH

= 272 for SF Direct Installed showerheads; 223 for MF Direct Installed showerheads

= 286 for SF Retrofit, Efficiency Kits, NC and TOS showerheads;

= 234 for MF Retrofit, Efficiency Kits, NC and TOS showerheads

Use Multifamily if: Building meets utility's definition for multifamily

GPH = Gallons per hour recovery of electric water heater calculated for 69.3°F temp rise (120-50.7), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 26.1

CF = Coincidence Factor for electric load reduction

= 0.0278

For example, DHWR summer coincident peak demand savings for single family home with direct installed showerheads can be calculated as follows:

ΔkW = (458.1 / 272) * 0.0278

= 0.0468 kW

NATURAL GAS SAVINGS

For gas water heating, annual energy savings per unit are calculated through the following formula:

$$\Delta\text{therms} = \frac{(\text{ShowerTemp} - \text{SupplyTemp}) \times 8.33\frac{\text{BTU}}{\text{gal}\cdot{}^{\circ}\text{F}} \times \text{GPM} \times \text{T}_{\text{shower-length}} \times \text{N}_{\text{persons}} \times \text{N}_{\text{units}} \times \text{SPCD} \times 365.25\,\frac{\text{days}}{\text{yr}} \times \text{SF}}{100{,}000\frac{\text{BTU}}{\text{therm}} \times \text{RE}}$$

Where:

100,000 = Conversion factor, 1 therm equals 100,000 BTU

RE = efficiency of gas water heater: 78% for single family[889] and 67% for multi family[890]

For example, for gas water heating, DHWR energy savings for single family home can be calculated as follows:

ΔTherms= ((101 – 50.7) * 8.33 * 2.24 * 7.8 * 2.56 * 1 * 0.6 * 365.25 * 0.4) / (100000 * 0.78)

= 21.1 therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

888 72.6% is the proportion of hot 120F water mixed with 50.7F supply water to give 101F shower water.

889 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%.

890 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.

MEASURE CODE: RS-DHW-DWHR-V02-220101

REVIEW DEADLINE: 1/1/2023

5.5 Lighting End Use

5.5.1 Compact Fluorescent Lamp (CFL)—Retired 12/31/2018, Removed in v8

5.5.2 ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)—Retired 12/31/2018, Removed in v8

5.5.3 ENERGY STAR Torchiere—Retired 12/31/2018, Removed in v8

5.5.4 Exterior Hardwired Compact Fluorescent Lamp (CFL) Fixture—Retired 12/31/2018, Removed in v8

5.5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture—Retired 12/31/2018, Removed in v8

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 96% Residential and 4% Commercial assumptions should be used.[891]

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.

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. However, in September 2019 this decision was revoked in a new DOE Final Rule.

The natural growth of LED market share however, has and will continue to grow over the lifetime of the LED measures installed. The TAC convened a Lamp Forecast Working Group to develop a forecast of the baseline growth of LED, based upon historical growth rates provided via CREED LightTracker data, comparisons of with and no-program states and review of projections provided by the Department of Energy.[892]

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

<u>Income Eligible Program Adjustments</u>

The Lamp Forecast Working Group also developed forecasts for estimated Income Eligible market growth in LEDs. These forecasts are used to provide a separate mid-life adjustment for programs supporting income eligible populations. Note that upstream lighting programs in DIY, Warehouse, and Big Box stores located in income eligible neighborhoods should not assume that all customers are from income eligible populations, as data has indicated that the product selection and low prices found in these stores attract customers from beyond.[893] A weighted blend of the two measure types (Income eligible and non-income eligible) can be used for DIY, Warehouse, and Big Box stores located in income eligible neighborhoods based upon primary evaluation research at these store types, or using a default of 30% income eligible customers.[894]

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[891] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY8, PY9 and CY2018 in store intercept survey results. See 'RESvCI Split_2019.xlsx'.

[892] US Department of Energy, "Energy Savings Forecast of Solid State Lighting in General Illumination Applications", December 2019. The resultant forecast is provided on the SharePoint site "Lamp Forecast Workbook.xls".

[893] Navigant and Itron, "CY2018 ComEd Income Eligible Product Discounts – Lighting NTG Recommendations".

[894] 30% of the respondents at the three Income Eligible Program stores where in-store intercepts were conducted met ComEd's income eligible definition; Navigant and Itron, "CY2018 ComEd Income Eligible Product Discounts – Lighting NTG Recommendations".

New Construction Programs

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

Early Replacement

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The average rated life for Decorative lamps on the ENERGY STAR Qualified Products list (accessed 6/16/2020) is approximately 17,000 hours, and for Directional Lamps is approximately 25,000 hours.

The deemed measure life is 6.9 years for exterior application of decorative lamps, and lifetimes are capped at 10 years for all other applications.[895]

For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFLs, the remaining life is 3,333 hours.[896]

DEEMED MEASURE COST

The price of LED lamps is falling quickly. Where possible, the actual cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following:[897]

Bulb Type	Year	Incandescent	LED	Incremental Cost	Incremental Cost for New Construction	Incremental Cost for New Construction
					(IECC 2015)	(IECC 2015)
Directional	2019 and on	$3.53	$5.18	$1.65	$0.41	$0.17
Decorative and Globe	2019 and on	$1.74	$3.40	$1.66	$0.42	$0.17

LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 0.109 for residential and in-unit multifamily bulbs,[898], 0.273

[895] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.
[896] Representing a third of the expected lamp lifetime.
[897] 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.
[898] 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.

for exterior bulbs[899] and 0.117 for unknown[900]. Use Multifamily if the building meets the utility's definition for multifamily.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the table below for default values.[901]

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below.

[899] 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.

[900] 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.

[901] See file "LED Lamp Updates 2021-06-09" for details on Guidehouse lamp wattage calculations based on equivalent baseline wattage and LED wattage of available ENERGY STAR product.

Decorative Lamps – ENERGY STAR Minimum Luminous Efficacy = 65Lm/W for all lamps

Bulb Type	Minimum Lumens	Maximum Lumens	LED Wattage ($Watts_{EE}$)	Baseline ($Watts_{Base}$)	Baseline for New Construction ($Watts_{Base}$)		Delta Watts (WattsEE)	Delta Watts for New Construction (WattsEE)	
					IECC 2015	IECC 2018		IECC 2015	IECC 2018
Omni-Directional 3-Way	1,100	1,999	14.7	100	36.0	23.2	85.3	21.3	8.5
	2,000	2,700	22.6	150	54.5	35.3	127.4	31.9	12.7
Globe (medium and intermediate bases less than 750 lumens)	150	349	3.0	25	8.5	5.2	22	5.5	2.2
	350	499	4.7	40	13.5	8.2	35.3	8.8	3.5
	500	574	5.7	60	19.3	11.1	54.3	13.6	5.4
	575	649	6.5	75	23.6	13.4	68.5	17.1	6.9
	650	1,000	8.2	100	31.2	17.4	91.8	23.0	9.2
Globe (candelabra bases less than 1050 lumens)	150	349	3.5	25	8.9	5.7	21.5	5.4	2.2
	350	499	4.4	40	13.3	8.0	35.6	8.9	3.6
	500	574	5.5	60	19.1	11.0	54.5	13.6	5.5
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	160	299	2.6	25	8.2	4.8	22.4	5.6	2.2
	300	499	4.3	40	13.2	7.9	35.7	8.9	3.6
	500	800	5.8	60	19.4	11.2	54.2	13.6	5.4
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	120	159	1.5	15	4.9	2.9	13.5	3.4	1.4
	160	299	2.7	25	8.3	4.9	22.3	5.6	2.2
	300	499	4.2	40	13.2	7.8	35.8	9.0	3.6
	500	650	5.5	60	19.1	11.0	54.5	13.6	5.5

Directional Lamps - ENERGY STAR Minimum Luminous Efficacy = 70Lm/W for <90 CRI lamps and 61 Lm/W for >=90CRI lamps.

For Directional R, BR, and ER lamp types:[902]

[902] From pg. 13 of the ENERGY STAR Specification for lamps v2.1

Bulb Type	Minimum Lumens	Maximum Lumens	LED Wattage ($Watts_{EE}$)	Baseline ($Watts_{Base}$)	Baseline for New Construction ($Watts_{Base}$)		Delta Watts (WattsEE)	Delta Watts for New Construction (WattsEE)	
					IECC 2015	IECC 2018		IECC 2015	IECC 2018
Reflector lamp types with medium screw bases (PAR20, PAR30(S,L), PAR38, R40, etc.) w/ diameter >2.25" (*see exceptions below)	400	649	7.0	50	17.8	11.3	43	10.8	4.3
	650	899	10.7	75	26.8	17.1	64.3	16.1	6.4
	900	1,049	13.9	90	32.9	21.5	76.1	19.0	7.6
	1,050	1,199	13.8	100	35.4	22.4	86.2	21.6	8.6
	1,200	1,499	15.9	120	41.9	26.3	104.1	26.0	10.4
	1,500	1,999	18.9	150	51.7	32.0	131.1	32.8	13.1
	2,000	4,200	27.3	250	83.0	49.6	222.7	55.7	22.3
Reflector lamp types with medium screw bases (PAR16, R14, R16, etc.) w/ diameter <2.25" (*see exceptions below)	280	374	4.6	35	12.2	7.6	30.4	7.6	3.0
	375	600	6.4	50	17.3	10.8	43.6	10.9	4.4
*BR30, BR40, or ER40	650	949	9.3	65	23.2	14.9	55.7	13.9	5.6
	950	1,099	12.7	75	28.3	18.9	62.3	15.6	6.2
	1,100	1,399	14.4	85	32.1	21.5	70.6	17.7	7.1
	1,400	1,600	16.6	100	37.5	24.9	83.4	20.9	8.3
	1,601	1,800	22.2	120	46.7	32.0	97.8	24.5	9.8
*R20	450	524	6.0	40	14.5	9.4	34.0	8.5	3.4
	525	750	7.1	45	16.6	10.9	37.9	9.5	3.8
*MR16	250	324	3.8	20.0	7.9	5.4	16.2	4.1	1.6
	325	369	4.8	25.0	9.9	6.8	20.2	5.1	2.0
	370	400	4.9	25.0	9.9	6.9	20.1	5.0	2.0

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.[903] 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.[904]

$$\text{Wattsbase} =$$

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

[903] See 'ESLampCenterBeamTool.xls'.

[904] 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.

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	LED Wattage ($Watts_{EE}$)	Baseline ($Watts_{Base}$)	Baseline for New Construction ($Watts_{Base}$)		Delta Watts (WattsEE)	Delta Watts for New Construction (WattsEE)	
					IECC 2015	IECC 2018		IECC 2015	IECC 2018
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)	120	399	4.0	25	9.3	6.1	21.0	5.3	2.1
	400	749	6.6	29	12.2	8.8	22.4	5.6	2.2
	750	899	9.6	43	18.0	12.9	33.4	8.4	3.3
	900	1,399	13.1	53	23.1	17.1	39.9	10.0	4.0
	1,400	1,999	16.0	72	30.0	21.6	56.0	14.0	5.6

ISR = In Service Rate or the percentage of lamps rebated that get installed

Program	Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Retail (Time of Sale)	81.5%[905]	8.9%	7.6%	98.0%[906]
Direct Install	94.5%[907]			

[905] 1st year in service rate is based upon analysis of ComEd PY8, PY9 and CY2018 intercept data (see 'Res Lighting ISR_2019.xlsx' for more information).

[906] 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.

[907] Consistent with assumption for standard LEDs (in the absence of evidence that it should be different for this bulb type). Based upon average of Navigant low income single family direct install field work LED ISR and 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

Program		Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Virtual Assessment followed by Unverified Self-Install		80.3%[908]	9.6%	8.1%	98%[909]
Efficiency Kits[910]	LED Distribution[911]	59%	13%	11%	83%
	School Kits[912]	60%	13%	11%	84%
	Direct Mail Kits[913]	66%	14%	12%	93%
	Direct Mail Kits, Income Qualified[914]	68%	15%	12%	95%
	Community Distributed Kits[915]	88%	4%	3%	95%

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[916] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[917]

ComEd: 1.1%

Ameren: 13.1%

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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.

[908] An equal weighted average of Direct Install and Direct Mail Kit ISRs. Interest and applicability of measures confirmed through virtual assessment.

[909] 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.

[910] 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.

[911] Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

[912] 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program. Final ISR assumptions are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, and second and third year estimates based on same proportion of future installs.

[913] Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

[914] Research from 2018 Ameren Illinois Income Qualified participant survey.

[915] Kits distributed in a community setting, targeted to income qualified communities. Research from 2018 Ameren Illinois Income Qualified participant survey.

[916] 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.

[917] Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY5,6 and 8 for Ameren.

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[918]
Exterior	2,475[919]
Unknown	1,020[920]

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

Bulb Location	WHFe
Interior single family	1.06 [921]
Multifamily in unit	1.04 [922]
Exterior or uncooled location	1.0
Unknown location	1.046[923]

Use Multifamily if: Building meets utility's definition for multifamily

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location:

ΔkWh = ((75 - 13) / 1000) * 0.840 * (1 – 0.011) * 763 * 1.06

= 41.6 kWh

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following

918 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.

919 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.

920 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.

921 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)

922 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)

923 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.

methodology for calculating the savings of these future installs.

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

The NTG factor for the Purchase Year (Year 1) should be applied.

HEATING PENALTY

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

ΔkWh[924] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49% for interior location [925]

= 0% for exterior location

= 42% for unknown location [926]

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [927]

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[928]	N/A	N/A	1.28

[924] Negative value because this is an increase in heating consumption due to the efficient lighting.

[925] 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.

[926] 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.

[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.

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location with a 2016 heat pump:

ΔkWh = - (((75 - 13) / 1000) * 0.840 * (1 – 0.011) * 763 * 0.49) / 2.04

= - 9.4 kWh

Mid-Life Baseline Adjustment

During the lifetime of an LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Natural growth of LED market share has, and will continue to grow over the lifetime of the measure, and so a single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings. See 'Lamp Forecast Workbook_2021.xls' for details.

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

Population	Lamp Type	Year from which adjustment is applied	Adjustment Factor applied to Annual kWh Savings
Income Eligible	Decorative	2029	67%
	Directional	2029	73%
All others	Decorative	2026	70%
	Directional	2026	61%

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location:

ΔkWh (2021-2024) = ((75 - 13) / 1000) * 0.840 * (1 – 0.011) * 763 * 1.06

= 41.7 kWh

ΔkWh (2025 on) = 41.7 * 0.61

= 25.4 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * WHFd * CF

Where:

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

Bulb Location	WHFd
Interior single family	1.11[929]
Multifamily in unit	1.07[930]

[929] 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.

[930] 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)

Bulb Location	WHFd
Exterior or uncooled location	1.0
Unknown location	1.083[931]

Use Multifamily if: Building meets utility's definition for multifamily

CF = Summer Peak Coincidence Factor for measure

= 0.109 for residential and in-unit multifamily bulbs[932], 0.273 for exterior bulbs,[933] and 0.117 for unknown.[934]

Use Multifamily if: Building meets utility's definition for multifamily

Other factors as defined above

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location:

ΔkW = (((75 - 13) / 1000) * 0.840 * (1 – 0.011) * 1.11* 0.109

= 0.0062 kW

NATURAL GAS SAVINGS

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

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

Where:

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

= 49% for interior[935]

= 0% for exterior location

= 42% for unknown location[936]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

931 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.

932 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.

933 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.

934 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.

935 Average result from REMRate modeling of several different configurations and IL locations of homes

936 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.

= 0.70 [937]

Other factors as defined above

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in single family interior location with gas heating at 70% total efficiency:

ΔTherms = - (((75 - 13) / 1000) * 0.840 * (1 – 0.011) * 763 * 0.49* 0.03412) / 0.70

= - 0.94 therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

Bulb replacement costs assumed in the O&M calculations are provided below:[938]

Lamp Type	Standard Incandescent	EISA Compliant Halogen	CFL	LED
Decorative	$1.74	$1.74	$2.50	$3.40
Directional	$3.53	$3.53	$4.50	$5.18

For non-exempt EISA bulb types defined above, in order to account for natural growth of LED over the lifetime of the measure, an equivalent annual levelized baseline replacement cost is calculated and applied over the life of the measure life.

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.42% are presented below:[939]

937 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

938 Baseline costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

939 See “Lamp Forecast Workbook_2020.xlsx” for calculation.

Lamp Type	Population	Location	NPV of replacement costs for period	Levelized annual replacement cost savings
			2021	2021
Decorative	Income eligible	Residential and in-unit Multi Family, and Unknown	$14.14	$1.45
		Exterior	$20.85	$3.09
	All others	Residential and in-unit Multi Family, and Unknown	$13.15	$1.35
		Exterior	$19.59	$2.90
Directional	Income eligible	Residential and in-unit Multi Family, and Unknown	$28.94	$2.96
		Exterior	$60.71	$6.21
	All others	Residential and in-unit Multi Family, and Unknown	$24.84	$2.54
		Exterior	$51.25	$5.19

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

MEASURE CODE: RS-LTG-LEDD-V13-220101

REVIEW DEADLINE: 1/1/2023

5.5.7 LED Exit Signs

Description

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a Multifamily building within unit (use 4.5.5 Commercial Exit Signs for multifamily common area exit signs). Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

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

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

Definition of Efficient Equipment

The efficient equipment is assumed to be an exit sign illuminated by LEDs.

Definition of Baseline Equipment

The baseline equipment is assumed to be an existing fluorescent or incandescent model.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 5 years.[940]

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.[941]

Loadshape

Loadshape C53 - Flat

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 100%.[942]

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:

940 Estimate of remaining life of existing unit being replaced.

941 Price includes new exit sign/fixture and installation. LED exit cost/unit is $22.50 from the NYSERDA Deemed Savings Database and assuming I labor cost of 15 minutes @ $40/hr.

942 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[943]
CFL (dual sided)	14W[944]
CFL (single sided)	7W
Unknown	7W

WattsEE = Actual wattage if known, if singled sided or unknown assume 2W, if dual sided assume 4W.[945]

HOURS = Annual operating hours

= 8766

WHF_e = Waste heat factor for energy; accounts for cooling savings from efficient lighting.

= 1.04[946]

Default if replacing incandescent fixture

ΔkWh = (35 – 2)/1000 * 8766 * 1.04

= 301 kWh

Default if replacing dual sided fluorescent fixture

ΔkWh = (14 – 4)/1000 * 8766 * 1.04

= 91 kWh

Default if replacing single sided fluorescent (or unknown) fixture

ΔkWh = (7 – 2)/1000 * 8766 * 1.04

= 46 kWh

HEATING PENALTY

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

ΔkWh[947] = - (((WattsBase - WattsEE) / 1000) * Hours * HF) / ηHeat

Where:

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

= 49%[948]

943 Based on review of available product.

944 Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

945 Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

946 The value is estimated at 1.04 (calculated as 1 + (0.45*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 3.1 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

947 Negative value because this is an increase in heating consumption due to the efficient lighting.

948 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [949]

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[950]	N/A	N/A	1.28

For example, a 2.0 COP (including duct loss) Heat Pump heated building:

If incandescent fixture: ΔkWh = -((35 – 2)/1000 * 8766 * 0.49) / 2

= -71 kWh

If unknown fixture ΔkWh = -((7 – 2)/1000 * 8766 * 0.49) / 2

= -10.7 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((WattsBase - WattsEE) / 1000) * WHF_d * CF$$

Where:

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. The cooling savings are only added to the summer peak savings.

=1.07[951]

CF = Summer Peak Coincidence Factor for measure

= 1.0

Default if incandescent fixture

ΔkW = (35 – 2)/1000 * 1.07 * 1.0

= 0.035 kW

Default if dual sided fluorescent fixture

ΔkW = (14 – 4)/1000 * 1.07 * 1.0

= 0.0107 kW

[949] 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.

[950] 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.

[951] The value is estimated at 1.11 (calculated as 1 + (0.45 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

Default if single sided fluorescent fixture

ΔkW = (7 – 2)/1000 * 1.07 * 1.0

= 0.0054 kW

NATURAL GAS SAVINGS

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

ΔTherms = - (((WattsBase - WattsEE) / 1000) * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49% [952]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [953]

Other factors as defined above

Default if incandescent fixture

ΔTherms = - (((35 - 2) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -6.9 therms

Default if dual sided fluorescent fixture

ΔTherms = - (((14 - 4) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -2.1 therms

Default if single sided fluorescent fixture

ΔTherms = - (((7 - 2) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -1.05 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

	Baseline Measures	
Component	Cost	Life (yrs)

[952] Average result from REMRate modeling of several different configurations and IL locations of homes

[953] 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[954]	1.37 years[955]

MEASURE CODE: RS-LTG-LEDE-V03-190101

REVIEW DEADLINE: 1/1/2024

954 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).
955 Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.

5.5.8 LED Screw Based Omnidirectional Bulbs

DESCRIPTION

This characterization provides savings assumptions for LED Screw Based Omnidirectional (e.g., A-Type lamps) lamps within the residential and multifamily sectors. This characterization assumes that the LED lamp is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program) a deemed split of 97% Residential and 3% Commercial assumptions should be used.[956]

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.1 became effective on 1/2/2017.

DEFINITION OF BASELINE EQUIPMENT

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) will require all general-purpose light bulbs between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards apply; in 2013 the 75 w lamp standards will apply, followed by restrictions on the 60 w and 40 w lamps in 2014. Since measures installed under this TRM all occur after 2014, baseline equipment are the values after EISA. These are shown in the baseline table below.

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

The natural growth of LED market share however, has and will continue to grow over the lifetime of the LED measures installed. The TAC convened a Lamp Forecast Working Group to develop a forecast of the baseline growth of LED, based upon historical growth rates provided via CREED LightTracker data, comparisons of with and no-program states and review of projections provided by the Department of Energy.[957]

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

<u>Income Eligible Program Adjustments</u>

The Lamp Forecast Working Group also developed forecasts for estimated Income Eligible market growth in LEDs. These forecasts are used to provide a separate mid-life adjustment for programs supporting income eligible populations. Note that upstream lighting programs in DIY, Warehouse, and Big Box stores located in income eligible neighborhoods should not assume that all customers are from income eligible populations, as data has indicated that the product selection and low prices found in these stores attract customers from beyond.[958] A weighted blend of the two measure types (Income eligible and non-income eligible) can be used for DIY, Warehouse, and Big Box stores located in income eligible neighborhoods based upon primary evaluation research at these store types, or

[956] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY8, PY9 and CY2018 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2019.xlsx'.
[957] US Department of Energy, "Energy Savings Forecast of Solid State Lighting in General Illumination Applications", December 2019. The resultant forecast is provided on the SharePoint site "Lamp Forecast Workbook.xls".
[958] Navigant and Itron, "CY2018 ComEd Income Eligible Product Discounts – Lighting NTG Recommendations".

using a default of 30% income eligible customers.[959]

New Construction Programs

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

Early Replacement

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

The deemed measure life is 8 years for exterior application and lifetimes are capped at 10 years for other applications.[960]

For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFL's, the remaining life is 3,333 hours.[961]

DEEMED MEASURE COST

The price of LED lamps is falling quickly. Where possible, the actual LED lamp cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following:[962]

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

LOADSHAPE

Loadshape R06 – Residential Indoor Lighting

Loadshape R07 – Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 0.128 for Residential and in-unit Multi Family bulbs,[963] 0.273

959 30% of the respondents at the three Income Eligible Program stores where in-store intercepts were conducted met ComEd's income eligible definition; Navigant and Itron, "CY2018 ComEd Income Eligible Product Discounts – Lighting NTG Recommendations".

960 Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

961 Representing a third of the expected lamp lifetime.

962 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.

963 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.

for exterior bulbs,[964] and 0.135 for unknown,[965]

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WHF_e$$

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:[966]

LED New and Baseline Assumptions Table

Minimum Lumens	Maximum Lumens	LED Wattage (WattsEE)	Baseline (WattsBase)	Baseline for New Construction (WattsBase)		Delta Watts (WattsEE)	Delta Watts for New Construction (WattsEE)	
				(IECC 2015)	(IECC 2018)		(IECC 2015)	(IECC 2018)
120	399	4.0	25	9.3	6.1	21.0	5.3	2.1
400	749	6.6	29	12.2	8.8	22.4	5.6	2.2
750	899	9.6	43	18.0	12.9	33.4	8.4	3.3
900	1,399	13.1	53	23.1	17.1	39.9	10.0	4.0
1,400	1,999	16.0	72	30.0	21.6	56.0	14.0	5.6
2,000	2,999	21.8	150	53.9	34.6	128.2	32.1	12.8
3,000	3,999	28.9	200	71.7	46.0	171.1	42.8	17.1
4,000	5,000	35.7	300	101.8	62.1	264.3	66.1	26.4

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

[964] 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.

[965] 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.

[966] See file "LED Lamp Updates 2021-06-09" for details on Guidehouse lamp wattage calculations based on equivalent baseline wattage and LED wattage of available ENERGY STAR product.

Program		Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate[967]
Retail (Time of Sale)		76.0%[968]	11.9%	10.1%	98.0%[969]
Direct Install		94.5%[970]			
Virtual Assessment followed by Unverified Self-Install		80.3%[971]	9.6%	8.1%	98.0%[972]
Efficiency Kits[973]	LED Distribution[974]	59%	13%	11%	83%
	School Kits[975]	60%	13%	11%	84%
	Direct Mail Kits[976]	66%	14%	12%	93%
	Direct Mail Kits, Income Qualified[977]	68%	15%	12%	95%
	Community Distributed Kits[978]	88%	4%	3%	95%

[967] Final ISR assumptions for efficiency kits are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, capped at 95%, and second and third year estimates based on same proportion of future installs. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[968] 1st year in service rate is based upon analysis of ComEd PY8, PY9 and CY2018 and Ameren PY8 intercept data (see 'RES Lighting ISR_2019.xlsx' for more information).

[969] 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.

[970] Based upon average of Navigant low income single family direct install field work LED ISR and Standard CFL assumption in the absence of better data, and is based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

[971] An equal weighted average of Direct Install and Direct Mail Kit ISRs. Interest and applicability of measures confirmed through virtual assessment.

[972] 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.

[973] 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.

[974] Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

[975] 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program. Final ISR assumptions are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, and second and third year estimates based on same proportion of future installs.

[976] Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

[977] Research from 2018 Ameren Illinois Income Qualified participant survey.

[978] Kits distributed in a community setting, targeted to income qualified communities. Research from 2018 Ameren Illinois Income Qualified participant survey.

Program	Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate[967]
Food Bank / Pantry Distribution[979]	80.3%[980]	9.6%	8.1%	98%[981]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[982] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[983]

ComEd: 0.8%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

Installation Location	Hours
Residential and in-unit Multi Family	1,089[984]
Exterior	2,475[985]
Unknown	1,159[986]

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

Bulb Location	WHFe
Interior single family	1.06 [987]
Multifamily in unit	1.04 [988]

979 Free bulbs provided through local food banks and food pantries.

980 1st year ISR is determined based on online surveys conduted for ComEd CY2018 Food Bank LED Distribution program. See 'CY2018 ComEd Foodbank LED Dist Survey Results_Navigant'.

981 In the absence of any program specific data, 98% lifetime ISR assumption is made based on similarity between 1st year ISR values with the Retail (Time of Sale) program and the 2nd and 3rd year installations are scaled accordingly.

982 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.

983 Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY8 for Ameren.

984 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.

985 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.

986 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.

987 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)

988 As above but using estimate of 45% of multifamily buildings in Illinois having central cooling (based on data from "Table

Bulb Location	WHFe
Exterior or uncooled location	1.0
Unknown location	1.051[989]

> **For example**, an 8W LED lamp, 450 lumens, is installed in the interior of a home. The customer purchased the lamp through a ComEd upstream program:
>
> ΔkWh = ((29.0 - 8) /1000) * 0.784 * (1 - 0.008) * 1,089 * 1.06
>
> = 18.9 kWh

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

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

The NTG factor for the Purchase Year should be applied.

> **For example:** using the assumptions from above, for an 8W LED, 450 Lumens purchased for the interior of a residential homes through a ComEd upstream program.
>
> $\Delta kWh_{2nd\ year\ installs}$ = ((29 - 8.0)/1000) * 0.106 * (1 – 0.008) * 1,089 * 1.06
>
> = 2.5 kWh
>
> $\Delta kWh_{3rd\ year\ installs}$ = ((29 – 8.0)/1000) * 0.09 * (1 – 0.008) * 1,089 * 1.06
>
> = 2.2 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):

ΔkWh[990] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49% for interior[991]

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)

989 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.

990 Negative value because this is an increase in heating consumption due to the efficient lighting.

991 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% for exterior or unheated location

= 42% for unknown location[992]

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use:[993]

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[994]	N/A	N/A	1.28

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

$\Delta kWh_{1st\ year}$ = - (((29 - 8) / 1000) * 0.784 * (1-0.008) * 1,089 * 0.42) / 2.0

= - 3.7 kWh

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

Mid-Life Baseline Adjustment

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. In December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that the more stringent standards (45 lumen per watt) prescribed in the 2007 EISA regulation to become effective in 2020 (known as the 'Backstop' provision), was not economically justified. However, natural growth of LED market share has, and will continue to grow over the lifetime of the measure, and so a single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings. See 'Lamp Forecast Workbook_2021.xls' for details.

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

Population	Year from which adjustment is applied	Adjustment Factor applied to Annual kWh Savings
Income Eligible	2029	81%
All others	2026	34%

992 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.

993 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.

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

ΔkWh (2021-2024) = ((29.0 – 8.0) /1000) * 0.784 * (1 - 0.008) * 1,089 * 1.06
= 18.9 kWh

ΔkWh (2025 on) = 18.9 * 0.34
= 6.4 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * WHFd * CF

Where:

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

Bulb Location	WHFd
Interior single family	1.11[995]
Multifamily in unit	1.07[996]
Exterior or uncooled location	1.0
Unknown location	1.093[997]

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF
Interior	0.128[998]
Exterior	0.273[999]
Unknown	0.135[1000]

Other factors as defined above

[995] 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.

[996] 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)

[997] 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.

[998] 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.

[999] 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.

[1000] 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.

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

ΔkW = ((29 - 8) / 1000) * 0.784 * (1-0.008) * 1.11 * 0.128
= 0.0023 kW

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

NATURAL GAS SAVINGS

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

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

Where:

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

= 49% for interior[1001]

= 0% for exterior location

= 42% for unknown location[1002]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1003]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

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

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.42% are presented below.[1004] 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:

1001 Average result from REMRate modeling of several different configurations and IL locations of homes

1002 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.

1003 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

1004 See “Lamp Forecast Workbook_2020.xlsx” for calculation.

Population	Location	NPV of replacement costs for period	Levelized annual replacement cost savings
		2022	2022
Income eligible	Residential and in-unit Multi Family, and Unknown	$10.01	$1.02
	Exterior	$16.81	$2.14
All others	Residential and in-unit Multi Family, and Unknown	$7.47	$0.76
	Exterior	$12.86	$1.64

MEASURE CODE: RS-LTG-LEDA-V12-220101

REVIEW DEADLINE: 1/1/2023

5.5.9 LED Fixtures

DESCRIPTION

This characterization provides savings assumptions for LED Fixtures and is broken into four ENERGY STAR fixture types: Indoor Fixtures (including track lighting, wall-wash, sconces, ceiling and fan lights), Task and Under Cabinet Fixtures, Outdoor Fixtures (including flood light, hanging lights, security/path lights, outdoor porch lights), and Downlight Fixtures.

For upstream programs, utilities should develop an assumption of the residential v commercial split and apply the relevant assumptions to each portion. A default deemed split of 97% Residential and 3% Commercial assumptions can be used based on Omnidirectional Bulbs.[1005]

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. Most of the lamp types in this measure are considered specialty so the baseline adjustments are consistent with the 5.5.6 LED Specialty Lamps.

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 tables below.

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. However, in September 2019 this decision was revoked in a DOE Final Rule.

The natural growth of LED market share however, has and will continue to grow over the lifetime of the LED measures installed. The TAC convened a Lamp Forecast Working Group to develop a forecast of the baseline growth of LED, based upon historical growth rates provided via CREED LightTracker data, comparisons of with and no-program states and review of projections provided by the Department of Energy.[1006]

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

[1005] 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'.
[1006] US Department of Energy, "Energy Savings Forecast of Solid State Lighting in General Illumination Applications", December 2019. The resultant forecast is provided on the SharePoint site "Lamp Forecast Workbook.xls".

<u>Income Eligible Program Adjustments</u>

The Lamp Forecast Working Group also developed forecasts for estimated Income Eligible market growth in LEDs. These forecasts are used to provide a separate mid-life adjustment for programs supporting income eligible populations. Note that upstream lighting programs in DIY, Warehouse, and Big Box stores located in income eligible neighborhoods should not assume that all customers are from income eligible populations, as data has indicated that the product selection and low prices found in these stores attract customers from beyond.[1007] A weighted blend of the two measure types (Income eligible and non-income eligible) can be used for DIY, Warehouse, and Big Box stores located in income eligible neighborhoods based upon primary evaluation research at these store types, or using a default of 30% income eligible customers.[1008]

<u>New Construction Programs</u>

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of a fixture is a function of its rated life and average hours of use. The rated life is 47,000 hours for indoor and downlight, 45,000 for task and cabinet, and 49,000 for outdoor fixtures.[1009] This would imply a lifetime of 51 years for indoor and downlight, 62 years for task and under cabinet, and 20 years for outdoor fixtures. However, all fixture lifetimes are capped at 15 years,[1010] 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:

Fixture Category	Incremental Cost	Incremental Cost for New Construction	
		(IECC 2015)	(IECC 2018)
Indoor	$26[1011]	$6.50	$2.60
Task /Under Cabinet	$18[1012]	$4.50	$1.80
Outdoor	$26	$6.50	$2.60
Downlight	$13	$3.25	$1.30

1007 Navigant and Itron, "CY2018 ComEd Income Eligible Product Discounts – Lighting NTG Recommendations".

1008 30% of the respondents at the three Income Eligible Program stores where in-store intercepts were conducted met ComEd's income eligible definition; Navigant and Itron, "CY2018 ComEd Income Eligible Product Discounts – Lighting NTG Recommendations".

1009 Average rated lives are based on the average rated lives of fixtures available on the ENERGY STAR qualifying list as of 2/26/2018.

1010 Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

1011 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.

1012 Incremental costs for task/under cabinet and downlight fixtures are from the 2018 Michigan Energy Measures Database.

LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 0.119 for residential and in-unit multifamily fixtures,[1013] 0.273 for exterior fixtures,[1014] and 0.127 for unknown.[1015]

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;[1016] see table below.

$Watts_{EE}$ = Actual wattage of LED fixture purchased / installed - If unknown, use default provided below:[1017]

Fixture Category	$Watts_{Base}$	Baseline for New Construction (WattsBase)		$Watts_{EE}$	Delta Watts for New Construction (WattsEE)	
		(IECC 2015)	(IECC 2018)		(IECC 2015)	(IECC 2018)
Indoor	88.5	38.9	29.0	22.4	16.5	6.6
Task /Under Cabinet	45.2	20.0	15.0	11.6	8.4	3.4
Outdoor	79.6	33.6	24.4	18.3	15.3	6.1
Downlight	72.8	33.4	25.6	20.3	13.1	5.3

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

= 1.0[1018]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1019] of the Utility Jurisdiction.

1013 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.

1014 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.

1015 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.

1016 See "Analysis" tab within file Residential LED Fixtures_Analysis_June 2018.xlsx for baseline calculations.

1017 Average of ENERGY STAR product category watts for products at or above the version 2.1 efficacy specification

1018 ISR recommendation for fixtures in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-22.

1019 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

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1020]

ComEd: 0.7%

Ameren: 6.6%

All other programs = 0

Hours = Average hours of use per year

Fixture Category	Hours
Indoor and Downlight	926[1021]
Task/Under Cabinet	730[1022]
Outdoor	2,475[1023]

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

Bulb Location	WHFe
Interior single family	1.06 [1024]
Multifamily in unit	1.04 [1025]
Exterior or uncooled location	1.0
Unknown location	1.051[1026]

For example, an indoor LED fixture is purchased through a ComEd retail program in 2019:

ΔkWh = ((88.5 – 22.4) /1000) * 1.0 * (1 – 0.007) * 926 * 1.06

= 64.4 kWh

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.

1020 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.

1021 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

1022 Task/under cabinet hours of use are estimated at 2 hours per day.

1023 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.

1024 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)

1025 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)

1026 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.

HEATING PENALTY

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

ΔkWh[1027] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49%[1028] for interior location

= 0% for exterior or unheated location

= 42%[1029] for unknown location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use:[1030]

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[1031]	N/A	N/A	1.28

For example, using the same indoor LED fixture that is installed in home with 2.0 COP Heat Pump (including duct loss) through a ComEd retail program in 2019:

$\Delta kWh_{1st\ year}$ = - (((88.5 – 22.4) / 1000) * 1.0 * (1 – 0.007) * 926 * 0.49) / 2.0

= - 14.9 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

Mid-Life Baseline Adjustment

During the lifetime of an LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Natural growth of LED market share has, and will continue to grow over the lifetime of the measure, and so a single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast

[1027] Negative value because this is an increase in heating consumption due to the efficient lighting.

[1028] 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.

[1029] 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.

[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.

[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.

decline in annual savings. For fixtures the directional lamp adjustments from the 'Lamp Forecast Workbook_2021.xls' are applied.

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

Population	Year from which adjustment is applied	Adjustment
Income Eligible	2029	73%
All others	2026	61%

For example, an indoor LED fixture is purchased through a ComEd retail program in 2021:

ΔkWh (2021-2024) = ((88.5 – 22.4) /1000) * 1.0 * (1 – 0.007) * 926 * 1.06
= 64.4 kWh

ΔkWh (2025 on) = 64.4 * 0.61
= 39.3 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * (1-Leakage) * WHFd * CF

Where:

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

Bulb Location	WHFd
Interior single family	1.11[1032]
Multifamily in unit	1.07[1033]
Exterior or uncooled location	1.0
Unknown location	1.093[1034]

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF
Interior	0.119[1035]
Exterior	0.273[1036]

[1032] 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.

[1033] 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)

[1034] 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.

[1035] 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.

[1036] 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.

Bulb Location	CF
Unknown	0.127[1037]

Other factors as defined above

For example, for the same indoor LED fixture that is installed in a single family interior location through a ComEd retail program in 2019, the demand savings are:

ΔkW = ((88.5 – 22.4) / 1000) * 1.0 * (1-0.007) * 1.11 * 0.119

= 0.0087 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

NATURAL GAS SAVINGS

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

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

Where:

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

= 49% for interior or unknown location[1038]

= 0% for exterior location

= 42% for unknown location[1039]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1040]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

1037 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.

1038 Average result from REMRate modeling of several different configurations and IL locations of homes

1039 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.

1040 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

DEEMED O&M COST ADJUSTMENT CALCULATION

Bulb replacement costs assumed in the O&M calculations are provided below:[1041]

Year	Standard Incandescent	CFL	LED
2019	$1.90	N/A	
2020	$1.90	N/A	
2021 & after	$1.90	$3.15	$4.35

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

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.42% are presented below.[1042] It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

Population	Location	NPV of replacement costs for period	Levelized annual replacement cost savings
		2021	2021
Income eligible	Indoor and Downlight, Task/Under Cabinet	$11.05	$0.76
	Exterior	$23.83	$1.64
All others	Indoor and Downlight, Task/Under Cabinet	$8.16	$0.56
	Exterior	$17.14	$1.18

MEASURE CODE: RS-LTG-LDFX-V05-220101

REVIEW DEADLINE: 1/1/2023

1041 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.
1042 See "Residential LED Fixtures_Analysis_2019b.xlsx" for calculation.

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.[1043]

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: [1044, 1045]

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

1043 See 'Christmas Lights Buying Guide – Hayneedle'.
1044 See 'Christmas Lights Buying Guide – Hayneedle'.
1045 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.[1046]

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[1047]
Mini	$15.38
C7	$21.42
C9	$17.28

Loadshape

Loadshape R16; Residential Holiday String Lighting

COINCIDENCE FACTOR

Due to the seasonal nature and evening operation of holiday string lights, there is no expected reduction in a utility's peak demand.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WHF_e$$

Where:

$Watts_{base}$ = Total wattage of the existing incandescent string lights = Bulb Wattage * # Bulbs; see table below for baseline bulb wattage assumptions

$Watts_{EE}$ = Actual total wattage of the new LED string lights = Bulb Wattage * # Bulbs. If unknown, assume total wattage of new LED string lights = Bulb Wattage * # Bulbs; see table below for LED bulb wattage assumptions

Where:

Bulb Wattage = Reference the "Bulb Wattage Assumptions" table below.

Bulb Wattage Assumptions[1048]

Type	Incandescent Bulb (Watts)	LED Bulb (Watts)
Mini	0.49	0.11
C7	5.00	0.31
C9	7.00	0.13

Bulbs = Actual quantity of bulbs on the string. If baseline is unknown, assume same as

1046 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'

1047 See file Holiday Lights Research and Calcs_2018.xlsx for CLEAResult research on holiday string lighting costs.

1048 Average wattages provided from market research by CLEAResult. See file Holiday Lights Research and Calcs_2018.xlsx.

the new string.

ISR = In Service Rate, or percentage of string lights that get installed. Derive from program evaluation analysis, otherwise assume 100%.

Leakage = Adjustment to account for the percentage of program string lights that move out (and in, if deemed appropriate) of the Utility Jurisdiction.

= For an exchange event, assume 0% if customer is required to be a utility customer. If not, determine leakage rate through evaluation. If customer is not required to be utility customer and if leakage is not determined through evaluation, use the deemed leakage rates LED omnidirectional bulbs sold through Upstream (TOS) programs:[1049]

ComEd:	1.6%
Ameren:	13.1%

Hours = Average hours of use per year

= 210 hours[1050]

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 through exchange event:

ΔkWh = ((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 1.0

HEATING PENALTY

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

ΔkWh[1051] = - (((WattsBase - WattsEE)/1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 49% for interior or unknown location[1052]
= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available, use:[1053]

1049 Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY8 for Ameren.
1050 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."
1051 Negative value because this is an increase in heating consumption due to the efficient lighting.
1052 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.
1053 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[1054]	N/A	N/A	1.28

For example, using the same 50-bulb mini LED string that is installed in home with 2.0 COP Heat Pump (including duct loss):

ΔkWh = - ((((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 0.49) / 2.0

= - 1.0 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Heating penalty if installed in a natural gas heated home, or if heating fuel is unknown.

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

Where:

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

= 49% for interior or unknown location [1055]

= 0% for exterior location

0.03412 = Converts kWh to Therms

ηHeat = Actual heating system efficiency

= 70% [1056]

[1054] 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.

[1055] Average result from REMRate modeling of several different configurations and IL locations of homes.

[1056] 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

For example, using the same 50-bulb mini LED string that is installed in a single family interior location with gas heating at 70% total efficiency:

$$\Delta therms = - ((((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 0.49 * 0.03412) / 0.70$$
$$= - 0.10 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-LTG-LEDH-V02-200101

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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

5.5.11 LED Nightlights

Description

This measure describes savings from LED nightlights. This characterization assumes that the LED nightlight is installed in a residential location.

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

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

Definition of Efficient Equipment

For this characterization to apply, the high-efficiency equipment must be a qualified LED nightlight.

Definition of Baseline Equipment

The baseline condition is assumed to be an incandescent/halogen nightlight.

Deemed Lifetime of Efficient Equipment

The estimated useful life of the is estimated is 8 years.[1057]

Deemed Measure Cost

Where possible, the actual cost should be used and compared to the baseline cost. If the incremental cost is unknown, assume the following:[1058]

Bulb Type	Year	Incandescent	LED	Incremental Cost
Nightlights	All	$2.84	$6.19	$3.35

Loadshape

Loadshape R07 - Residential Outdoor Lighting

Coincidence Factor

Demand savings is assumed to be zero for this measure.

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

$Watts_{base}$ = Actual wattage if known, if unknown, assume 7W.[1059]

[1057] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2. and p.3.

[1058] Average cost data provided in Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March 2018.

[1059] Based on Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March 2018.

$Watts_{EE}$ = Actual wattage of LED purchased / installed.

ISR = In Service Rate or the percentage of nightlights rebated that get installed

Program	Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Retail (Time of Sale)	84.0%[1060]	7.6%	6.4%	98.0%[1061]
Direct Install	96.9%[1062]			
School Kits	60%[1063]	13%	11%	84%

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1064] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1065]

ComEd: 2.0%

Ameren: 13.1%

Hours = Average hours of use per year

= 4,380[1066]

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

Bulb Location	WHFe
Interior single family	1.06 [1067]

1060 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).

1061 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.

1062 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.

1063 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

1064 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.

1065 Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY5,6 and 8 for Ameren (see for more information).

1066 Assumes nightlight is operating 12 hours per day, consistent with the 2016 Pennsylvania TRM.

1067 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

Bulb Location	WHFe
Multifamily in unit	1.04 [1068]
Unknown location	1.054[1069]

For example, a 0.3W LED nightlight is direct installed in single family interior location within ComEd territory:

ΔkWh = ((7 – 0.3) / 1000) * 0.969 * (1 – 0) * 4380 * 1.06

= 30.1 kWh

HEATING PENALTY

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

ΔkWh[1070] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / ηHeat

Where:=(

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

= 49% for interior[1071]

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [1072]

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[1073]	N/A	N/A	1.28

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)

1068 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)

1069 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.

1070 Negative value because this is an increase in heating consumption due to the efficient lighting.

1071 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.

1072 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.

1073 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

For example, a 0.3W LED nightlight is direct installed in single family interior location with a 2016 heat pump:

ΔkWh = - (((7 – 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49) / 2.04

= - 6.83 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * (1-Leakage) * WHFd * CF

Where:

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

Bulb Location	WHFd
Interior single family or unknown location	1.11[1074]
Multifamily in unit	1.07[1075]
Unknown location	1.098[1076]

CF = Summer Peak Coincidence Factor for measure.

= 0

NATURAL GAS SAVINGS

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

Δtherms = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49% for interior[1077]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency

= 0.70 [1078]

Other factors as defined above

[1074] 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.

[1075] 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)

[1076] 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.

[1077] Average result from REMRate modeling of several different configurations and IL locations of homes

[1078] 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:

Δtherms = - (((7 – 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49* 0.03412) / 0.70

= - 0.68 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE: RS-LTG-NITL-V01-190101

REVIEW DEADLINE: 1/1/2025

5.5.12 Connected LED Lamps

DESCRIPTION

Many home devices in the market have become integrated with smart technology in recent years. Home devices able to connect to Wifi or a mobile network allow the user to control the device over the internet. This measure defines the savings associated with connected lighting. Connected LEDs allow for remote user control through a smart device, such as smart phone, tablet, or smart speaker. The standard LED provides light in one shade at one lumen level and color temperature. Connected LEDs have options integrated that allow for customizable color, color temperature, and lumen output. The Connected LED can also be turned on and off with a set schedule or controlled remotely. Savings from this measure come from both reduced hours of operation and dimming.

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

DEFINITION OF EFFICIENT EQUIPMENT

For this characterization to apply, the efficient condition must be LED lighting that is controlled by a smart device. The savings for this measure are the estimated incremental control savings compared to a non-connected efficient lamp. Some connected LEDs come with hubs for managing their operations. Connected LEDs with hubs do not qualify for this savings characterization, as the energy use by the hub cancels out the savings attributed to the connectivity of the lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the efficient LED without the connected capabilities.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 6.1 years for exterior application.[1079] For all other applications, lifetimes are capped at 10 years.[1080]

DEEMED MEASURE COST

The incremental cost can be assumed to be $20, the difference between the average cost of the baseline non-connected LED and the average cost of the connected LED.[1081]

LOADSHAPE

Loadshape R06 – Residential Indoor Lighting

Loadshape R07 – Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 0.128 for Residential and in-unit Multi Family bulbs,[1082] 0.273

1079 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.

1080 Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

1081 Estimate based on review of available product and estimates provided in King J., ACEEE, "Energy Impacts of Smart Home Technologies", April 2018.

1082 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.

for exterior bulbs,[1083] and 0.135 for unknown.[1084]

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

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (((Watts_{EE}/1000) * HOURS * SVGe * WHFe) - Standby_{kWh}) * ISR * (1 - Leakage)$$

Where:

WattsEE = Actual wattage of LED. If unknown, then use the following default assumption:

= 0.034[1085]

HOURS = Average hours of use per year

Installation Location	Hours
Residential and in-unit Multi Family	1,089[1086]
Exterior	2,475[1087]
Unknown	1,159[1088]

SVGe = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below

= 0.30[1089]

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

Program		Weighted Average 1st year In Service Rate (ISR)[1090]
Retail (Time of Sale)		98.0%
Direct Install		96.9%
Efficiency	LED Distribution	83%

[1083] 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.

[1084] 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.

[1085] Connecticut LED Lighting Study Report (R154). Average connected wattage of lamps in dining room, living space, bedroom, bathroom, and kitchen spaces.

[1086] 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.

[1087] 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.

[1088] 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.

[1089] Mid Atlantic Technical Reference Manual Version 8, May 2018. SVGe value adjusted downward (from original TRM value of 0.49 to 0.30) based on phone conversations with Navigant in support of the MEMD.

[1090] ISRs are consistent with the LED Screw Based Standard Lamp measure, however since 2nd and 3rd year savings for this measure are so minimal, for ease of implementation the 3 year installs are discounted using the real discount rate to a single assumption.

Program		Weighted Average 1st year In Service Rate (ISR) [1090]
Kits	School Kits	84%
	Direct Mail Kits	92%
Food Bank / Pantry Distribution		98%

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1091] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1092]

ComEd: 0.8%

Ameren: 13.1%

All other programs = 0

WHFe = Waste heat factor for energy to account for cooling savings

Bulb Location	WHFe
Interior single family	1.06 [1093]
Multifamily in unit	1.04 [1094]
Exterior or uncooled location	1.0
Unknown location	1.051 [1095]

StandbykWh = Standby power draw of the controlled lamp. Use actual value from manufacturer specification. If not known then assume:

= 0.35 kWh[1096]

1091 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.

1092 Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY8 for Ameren.

1093 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)

1094 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)

1095 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.

1096 Laccarino, et. Al. "Only as Smart as its owner: A connected device study". Cadmus study presented at ACEEE Summer Study on Energy Efficiency in Buildings, 2018.

For example, a 9W Connected LED is purchased through a ComEd upstream program.

$\Delta kWh_{1st\ year\ installs}$ = (((9/1000) * 1,089 * 0.3 * 1.051) – 0.35) * 0.9 * (1 – 0.008)

= 2.45 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kWh = (Watts_{EE}/1000) * SVGd * WHFd * ISR * (1 - Leakage) * CF$$

Where:

SVGd = Percentage of annual lighting demand saved by lighting control; determined on a site-specific basis or using default below

= 0.30[1097]

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

Bulb Location	WHFd
Interior single family	1.11[1098]
Multifamily in unit	1.07[1099]
Exterior or uncooled location	1.0
Unknown location	1.093[1100]

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF
Interior	0.128[1101]
Exterior	0.273[1102]
Unknown	0.135[1103]

[1097] Mid Atlantic Technical Reference Manual Version 8, May 2018. SVGe value adjusted downward (from original TRM value of 0.49 to 0.30) based on phone conversations with Navigant in support of the MEMD.

[1098] 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.

[1099] 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)

[1100] 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.

[1101] 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.

[1102] 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.

[1103] 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.

For example, a 9W Connected LED is purchased through a ComEd upstream program.

$\Delta kW_{1st\ year\ installs}$ = (((9/1000) * 0.3 * 1.093)) * 0.9 * (1 – 0.008)

= 0.0026 kW

NATURAL GAS SAVINGS

NA

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

NA

DEEMED O&M COST ADJUSTMENT CALCULATION

NA

MEASURE CODE: RS-LTG-LEDC-V01-200101

REVIEW DEADLINE: 1/1/2023

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 when a blower door test is not conducted.

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. Savings are provided for prescriptive air sealing measures when a blower door test is not conducted.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1104]

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

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers.[1105] 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

[1104] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[1105] 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.

capacity market.

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

= 68%[1106]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1107]

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

= 46.6%[1108]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Blower Door Test

Required methodology when blower door testing is conducted.

ΔkWh = ΔkWh_cooling + ΔkWh_heatingElectric + ΔkWh_heatingGas

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

= [(((CFM50_existing - CFM50_new)/N_cool) * 60 * 24 * CDD * DUA * 0.018) / (1000 * ηCool) * LM * $ADJ_{AirSealingCool}$] * $IE_{NetCorrection}$ * %Cool

CFM50_existing = Infiltration at 50 Pascals as measured by blower door before air sealing.

= Actual

CFM50_new = Infiltration at 50 Pascals as measured by blower door after air sealing.

= Actual

N_cool = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

=Dependent on location and number of stories:[1109]

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

[1106] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[1107] 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)'.
[1108] 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.
[1109] 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".

Climate Zone (City based upon)	N_cool (by # of stories)			
	1	1.5	2	3
5 (Paducah, KY)	43.6	38.6	35.4	31.3

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

CDD = Cooling Degree Days

= Dependent on location:[1110]

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

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

= 0.75 [1111]

0.018 = Specific Heat Capacity of Air (Btu/ft^3*°F)

1000 = Converts Btu to kBtu

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

= Actual (where new or where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1112] or if unknown assume the following:[1113]

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

LM = Latent multiplier to account for latent cooling demand[1114]

1110 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

1111 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.

1112 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1113 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.

1114 Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc".

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

$ADJ_{AirSealingCool}$ = Adjustment for cooling savings to account for innacuracies in engineering algorithms[1115]

Measure	$ADJ_{AirSealingCool}$
Air sealing and attic insulation	121%
Air sealing without attic insulation	100%

$IE_{NetCorrection}$ = 100% if not income eligible or air sealing is installed without attic insulation.

= 110% if installing air sealing and attic insulation in income eligible projects with a deemed NTG value of 1.0 to offset net savings adjustment inherent when using $ADJ_{AirSealingCool}$ of 121% [1116]

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[1117]	66%

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

= [(((CFM50_existing - CFM50_new)/N_heat) * 60 * 24 * HDD * 0.018) / (ηHeat * 3,412)] *%ElectricHeat

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

[1115] As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.
These adjustment factors are based on a consumption data analysis using matching to non-participants. The values are therefore between net and gross with respect to free ridership. Like all consumption data analyses, they are net with respect to participant spillover and gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to the savings will be determined as part of the annual SAG net-to-gross process.

[1116] The additional value of 10% was selected to acknowledge that some portion of the regression-derived adjustment factors accounts for gross impact effects, and that removing net effects embedded in the adjustment factors would increase savings to some degree. A review of historical NTG values for air sealing and insulation measures in non-income eligible populations did not provide definitive guidance for estimating the net component of the adjustment factors. Historically, free ridership has ranged from 9% to 26% for like measures, and spillover has ranged from 1% to 14%, while NTGs have ranged from 0.75 to 1.05. The midpoint of the NTG range would be 0.90, a 10% reduction from 1.0.

[1117] Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

= Based on climate zone, building height and exposure level:[1118]

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:[1119]

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

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1120] or if not available refer to default table below:[1121]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown (for use in program evaluation only)[1122]	N/A	N/A	1.28

[1118] 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".

[1119] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.

[1120] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[1121] 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.

[1122] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration,

3412 = Converts Btu to kWh

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[1123], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

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

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

ΔkWh = ΔkWh_cooling + ΔkWh_heating

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

= 220 + 1,199

= 1,419 kWh

ΔkWh_heatingGas = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3 * $ADJ_{AirSealingHeatFan}$

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

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.

[1123] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People’s Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd’s 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

= 3.14%[1124]

29.3 = kWh per therm

$ADJ_{AirSealingHeatFan}$ = Adjustment for fan savings during heating season to account for innacuracies in engineering algorithms[1125]

Measure	$ADJ_{AirSealingHeatFan}$
Air sealing and attic insulation	107%
Air sealing without attic insulation	100%

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

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

ΔkWh_heatingGas = 76.3 * 0.0314 * 29.3 * 107%

= 75.1 kWh

Methodology 2: Prescriptive Infiltration Reduction Measures[1126]

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

HEATING SAVINGS

ΔkWh_heating = $(\Delta kWh_{gasket} * n_{gasket} + \Delta kWh_{windows} * sf_{windows} + \Delta kWh_{sweep} * n_{sweep} + \Delta kWh_{sealing} * lf_{sealing} + \Delta kWh_{WX} * lf_{WX}) * ADJ_{RxAirsealing} * ISR$

Where:

ΔkWh_{gasket} = Annual kWh savings from installation of air sealing gasket on an electric outlet

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

1124 F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

1125 As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. These adjustment factors are based on a consumption data analysis using matching to non-participants. The values are therefore between net and gross with respect to free ridership. Like all consumption data analyses, they are net with respect to participant spillover and gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to the savings will be determined as part of the annual SAG net-to-gross process.

1126 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.

n_{gasket} = Number of gaskets installed

$\Delta kWh_{windows}$ = Annual kWh savings from installation of Shrink-Fit Window Kit[1127]

Climate Zone (City based upon)	$\Delta kWh_{windows}$ / sf Electric Resistance	$\Delta kWh_{windows}$ / sf Heat Pump
1 (Rockford)	4.0	2.1
2 (Chicago)	3.9	2.0
3 (Springfield)	3.3	1.7
4 (Belleville)	2.5	1.3
5 (Marion)	2.6	1.3

$sf_{windows}$ = square footage of shrink-fit window film

ΔkWh_{sweep} =Annual kWh savings from installation of door sweep

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

n_{sweep} = Number of sweeps installed

$\Delta kWh_{sealing}$ = Annual kWh savings from foot of caulking, sealing, or polyethlylene tape

Climate Zone (City based upon)	$\Delta kWh_{sealing}$ / ft	
	Electric Resistance	Heat Pump
1 (Rockford)	11.6	5.8
2 (Chicago)	11.2	5.6
3 (Springfield)	9.7	4.8
4 (Belleville)	7.7	3.9
5 (Marion)	7.9	3.9

$lf_{sealing}$ = linear feet of caulking, sealing, or polyethylene tape

ΔkWh_{WX} = Annual kWh savings from window weatherstripping or door weatherstripping

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

lf_{WX} = Linear feet of window weatherstripping or door weatherstripping

[1127] Prescriptive savings are based upon "Cost Benefit Analysis for 2018, Annual Report submitted to Virginia Natural Gas, Inc., submitted by Nexant." July 31, 2018. Adjusted for relative HDD of Virginia Beach VA with the IL climate zones. See "Window Film Savings Calculation.xlsx" for more information.

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[1128]

= 80%

ISR = In service rate of weatherization kits dependant on install method as listed in table below.[1129]

Selection	ISR
Distributed School Weatherization Kits	0.58[1130]
Distributed Self-Install Income-Qualified Kits[1131] Weatherstripping Outlet and Switch Gaskets Window Kit Other Distributed Self-Install Income-Qualified Measures	 0.63 0.51 0.57 0.57[1132]
Opt-in Weatherization Kits V-seal weatherstripping Cell foam tape weatherstripping Rope Caulk Switch and outlet gaskets Door sweep Other Self-Install Weatherization Measures	 0.57 0.62 0.44 0.60 0.56 0.56[1133]
Direct Install, Retail	1.0

COOLING SAVINGS

ΔkWh = ΔkWh_cooling

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

= [(((ΔCFM50_prescriptive)/N_cool) * 60 * 24 * CDD * DUA * 0.018) / (1000 * ηCool) * LM * $ADJ_{AirSealingCool}$] * $IE_{NetCorrection}$ * %Cool

ΔCFM50_prescriptive = Infiltration at 50 Pascals.

= See table below

1128 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.

1129 For any airsealing kit measure, if research indicates that a certain percentage of participants who indicated during the original ISR survey that they plan to install are found to have actually installed at a later date, these future installs can be claimed as 2nd or 3rd year installs through an errata.

1130 ILLUME Advising LLC. School-Based Energy Education Programs: Goals, Challenges, and Opportunities. October 2015. See result for AEP Ohio Weather stripping/door sweep/gaskets kit in table on page 17.

1131 Guidehouse. Income Eligible Gas Kits ISR Special Study Results. June 16, 2020.

1132 Straight average of other measures.

1133 Guidehouse survey research for Nicor Gas, July 14, 2021.

Typical Reductions in Leakage[1134]

Technology	Application	ΔCFM50[1135]
Weather Stripping	Single Door	25.5 CFM/door
	Double Door	0.73 CFM/ft^2
	Casement Window	0.036 CFM/lf of crack
	Double Horizontal Slider, Wood	0.473 CFM/lf of crack
	Double-Hung	1.618 CFM/lf of crack
	Double-Hung, with Storm Window	0.164 CFM/lf of crack
	Average Weatherstripping	0.639 CFM/lf of crack
Caulking	Piping/Plumbing/Wiring Penetrations	10.9 CFM each
	Window Framing, Masonry	1.364 CFM/ft^2
	Window Framing, Wood	0.382 CFM/ft^2
	Door Frame, Masonry	1.018 CFM/ft^2
	Door Frame, Wood	0.364 CFM/ft^2
	Average Window/Door Caulking	0.689 CFM/lf of crack
Average Window/Door Caulking and Weather Stripping		0.664 CFM/lf of crack
Gasket	Electrical Outlets	6.491 CFM each

Other factors as defined above.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location:[1136]

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)

= 68%[1137]

1134 ASHRAE, 2001 AHSRAE Handbook – Fundamentals, Chapter 26, Table 1. Effective Air Leakage Areas (Low-Rise Residential Applications Only).

1135 ΔCFM50 is estimated by dividing the Effective Air Leakage Area by 0.055. See page 83, The Energy Conservatory, Minneapolis Blower Door Operation Manual, http://energyconservatory.com/wp-content/uploads/2014/07/Blower-Door-model-3-and-4.pdf

1136 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.

1137 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% [1138]

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

= 46.6% [1139]

Other factors as defined above.

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

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

ΔkW_{SSP} = 220 / 570 * 0.68

= 0.26 kW

ΔkW_{PJM} = 220 / 570 * 0.466

= 0.18 kW

NATURAL GAS SAVINGS

Methodology 1: Blower Door Test

Required methodology when blower door testing is conducted.

If Natural Gas heating:

$$\Delta Therms = (((CFM50\_existing - CFM50\_new)/N\_heat) * 60 * 24 * HDD * 0.018) / (\eta Heat * 100{,}000) * ADJ_{AirSealingGasHeat} * IE_{NetCorrection} * \%GasHeat$$

Where:

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone and building height:[1140]

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

[1138] 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)'.

[1139] 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.

[1140] 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".

= dependent on location:[1141]

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

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate, assuming 85% distribution efficiency if only equipment efficiency is available).[1142] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1143] or if Equipment Efficiency is not available, use Section 5.3 to select the appropriate equipment efficiency for the project.

$ADJ_{AirSealingGasHeat}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms:[1144]

Measure	$ADJ_{AirSealingGasHeat}$
Air sealing and attic insulation	72%
Air sealing without attic insulation	100%

$IE_{NetCorrection}$ = 100% if not income eligible or air sealing is installed without attic insulation

= 110% if installing air sealing and attic insulation in income eligible projects with a deemed NTG value of 1.0 to offset net savings adjustment inherent when using $ADJ_{AirSealingGasHeat}$ of 72%[1145]

%GasHeat = Percent of homes that have gas space heating

[1141] 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..

[1142] 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.

[1143] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[1144] As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. These adjustment factors are based on a consumption data analysis using matching to non-participants. The values are therefore between net and gross with respect to free ridership. Like all consumption data analyses, they are net with respect to participant spillover and gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to the savings will be determined as part of the annual SAG net-to-gross process.

[1145] The additional value of 10% was selected to acknowledge that some portion of the regression-derived adjustment factors accounts for gross impact effects, and that removing net effects embedded in the adjustment factors would increase savings to some degree. A review of historical NTG values for air sealing and insulation measures in non-income eligible populations did not provide definitive guidance for estimating the net component of the adjustment factors. Historically, free ridership has ranged from 9% to 26% for like measures, and spillover has ranged from 1% to 14%, while NTGs have ranged from 0.75 to 1.05. The midpoint of the NTG range would be 0.90, a 10% reduction from 1.0.

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[1146], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

Other factors as defined above.

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

Assume a 2 story non-income eligible single family home in Chicago completes air sealing, installs attic insulation, has a gas furnace with system efficiency of 72%, and has pre and post blower door test results of 3,400 and 2,250:

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

= 78.5 therms

Methodology 2: Prescriptive Infiltration Reduction Measures[1147]

Savings shall only be calculated via Methodology 2 when a blower door test is not conducted.

$\Delta therms = (\Delta therms_{gasket} * n_{gasket} + \Delta therms_{windows} * sf_{windows} + \Delta therms_{sweep} * n_{sweep} + \Delta therms_{sealing} * lf_{sealing} + \Delta therms_{WX} * lf_{WX}) * ADJ_{RxAirsealing} * ISR$

Where:

$\Delta therms_{gasket}$ = Annual therm savings from installation of air sealing gasket on an electric outlet

Climate Zone (City based upon)	$\Delta therms_{gasket}$ / gasket Gas Heat
1 (Rockford)	0.49
2 (Chicago)	0.47
3 (Springfield)	0.41
4 (Belleville)	0.33
5 (Marion)	0.33

1146 Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

1147 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.

n_{gasket} = Number of gaskets installed

$\Delta therms_{windows}$ = Annual therm savings from installation of Shrink-Fit Window Kit:[1148]

Climate Zone (City based upon)	$\Delta therms_{windows}$ / sf Gas Heat
1 (Rockford)	0.191
2 (Chicago)	0.183
3 (Springfield)	0.156
4 (Belleville)	0.121
5 (Marion)	0.123

$sf_{windows}$ = square footage of shrink-fit window film

$\Delta therms_{sweep}$ = Annual therm savings from installation of door sweep

Climate Zone (City based upon)	$\Delta therms_{sweep}$ / sweep Gas Heat
1 (Rockford)	9.46
2 (Chicago)	9.13
3 (Springfield)	7.92
4 (Belleville)	6.31
5 (Marion)	6.45

n_{sweep} = Number of sweeps installed

$\Delta therms_{sealing}$ = Annual therm savings from foot of caulking, sealing, or polyethlylene tape

Climate Zone (City based upon)	$\Delta therms_{sealing}$ / ft Gas Heat
1 (Rockford)	0.54
2 (Chicago)	0.52
3 (Springfield)	0.45
4 (Belleville)	0.36
5 (Marion)	0.37

$lf_{sealing}$ = linear feet of caulking, sealing, or polyethylene tape

$\Delta therms_{WX}$ = Annual therm savings from window weatherstripping or door weatherstripping

Climate Zone (City based upon)	$\Delta therms_{sx}$ / ft Gas Heat
1 (Rockford)	0.63
2 (Chicago)	0.61
3 (Springfield)	0.53
4 (Belleville)	0.42
5 (Marion)	0.43

1148 Prescriptive savings are based upon "Cost Benefit Analysis for 2018, Annual Report submitted to Virginia Natural Gas, Inc., submitted by Nexant." July 31, 2018. Adjusted for relative HDD of Virginia Beach VA with the IL climate zones. See "Window Film Savings Calculation.xlsx" for more information.

lf_{WX} = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[1149]

= 80%

Other assumptions as defined above

Mid-Life adjustment

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

Efficiency Assumption	System Type	New Baseline Efficiency
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER
ηHeat	Electric Resistance	1.0 COP
	Heat Pump (8.2HSPF/3.413)*0.85	2.04 COP
	Furnace 80% AFUE * 0.85	68% AFUE
	Boiler	84% 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.[1150] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AIRS-V11-220101

REVIEW DEADLINE: 1/1/2024

[1149] 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.

[1150] 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.[1151]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers.[1152] 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 capacity market.

[1151] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1152] 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%[1153]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1154]

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

= 46.6%[1155]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heatingElectric + ΔkWh_heatingGas)

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor) * 24 * CDD * DUA) / (1000 * ηCool)) * $ADJ_{BasementCool}$ * %Cool

R_added = R-value of additional spray foam, rigid foam, or cavity insulation.

R_old_AG = R-value value of foundation wall above grade.

= Actual, if unknown assume 1.0.[1156]

L_basement_wall_total = Length of basement wall around the entire insulated perimeter (ft)

H_basement_wall_AG = Height of insulated basement wall above grade (ft)

Framing_factor = Adjustment to account for area of framing when cavity insulation is used

= 0% if Spray Foam or External Rigid Foam

= 25% if studs and cavity insulation[1157]

24 = Converts hours to days

CDD = Cooling Degree Days

1153 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1154 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)'.

1155 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.

1156 ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991.

1157 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

= Dependent on location and whether basement is conditioned:[1158]

Climate Zone (City based upon)	Conditioned CDD 65	Unconditioned CDD 65[1159]
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[1160]	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 [1161]

1000 = Converts Btu to kBtu

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

= Actual (where new or where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1162] or if unknown assume the following:[1163]

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

$ADJ_{BasementCool}$ = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[1164]

= 80%

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%

1158 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

1159 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.

1160 Weighted based on number of occupied residential housing units in each zone.

1161 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.

1162 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1163 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.

1164 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%.

Central Cooling?	%Cool
No	0%
Unknown (for use in program evaluation only)[1165]	66%

ΔkWh_heatingElectric = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= [(((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) + ((1/R_old_BG - 1/(R_added+R_old_BG)) * L_basement_wall_total * (H_basement_wall_total - H_basement_wall_AG) * (1-Framing_factor))] * 24 * HDD) / (3,412 * ηHeat)) * $ADJ_{BasementHeat}$ *%ElectricHeat

Where

R_old_BG = R-value value of foundation wall below grade (including thermal resistance of the earth) [1166]

= dependent on depth of foundation (H_basement_wall_total – H_basement_wall_AG):

= Actual R-value of wall plus average earth R-value by depth in table below

Below Grade R-value									
Depth below grade (ft)	0	1	2	3	4	5	6	7	8
Earth R-value (°F-ft^2-h/Btu)	2.44	4.50	6.30	8.40	10.44	12.66	14.49	17.00	20.00
Average Earth R-value (°F-ft2-h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69
Total BG R-value (earth + R-1.0 foundation) default	3.44	4.47	5.41	6.41	7.42	8.46	9.46	10.53	11.69

H_basement_wall_total = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:[1167]

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[1168]	4,860	2,895

1165 Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

1166 Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

1167 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.

1168 Weighted based on number of occupied residential housing units in each zone.

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1169] or if not available refer to default table below:[1170]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown (for use in program evaluation only)[1171]	N/A	N/A	1.28

$ADJ_{BasementHeat}$ = Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[1172]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[1173], use the following table:

1169 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1170 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.

1171 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.

1172 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%.

1173 Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= [((((1/2.25 - 1/(13 + 2.25))*(20+25+20+25) * 3 * (1 - 0)) * 24 * 281 * 0.75)/(1000 * 10.5)) * 0.8 * 100%] + [(((((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 * 100%]

= (39.4 + 860.9)

= 900.3 kWh

ΔkWh_heatingGas = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

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

= 3.14%[1174]

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section :

= 78.3 * 0.0314 * 29.3

= 72.0 kWh

SUMMER COINCIDENT PEAK DEMAND

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

[1174] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.

= dependent on location:[1175]

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[1176]	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% [1177]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72% [1178]

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

= 46.6% [1179]

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:

ΔkW_{SSP} = 39.4 / 570 * 0.68

= 0.047 kW

ΔkW_{PJM} = 39.4 / 570 * 0.466

= 0.032 kW

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms = (((((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) + ((1/R_old_BG - 1/(R_added+R_old_BG)) * L_basement_wall_total * (H_basement_wall_total - H_basement_wall_AG) * (1-Framing_factor))) * 24 * HDD) / (ηHeat * 100,000)) * $ADJ_{BasementHeat}$ * %GasHeat

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate, assuming 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for

[1175] 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.
[1176] Weighted based on number of occupied residential housing units in each zone.
[1177] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[1178] 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)'.
[1179] 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.

degradation over time,[1180] or if unknown assume 72% for existing system efficiency[1181]

%GasHeat = Percent of homes that have gas space heating

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[1182], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 72% efficient furnace:

= (((((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0)) + ((1/8.67 - 1/(13 + 8.67)) * (20+25+20+25) * 4 * (1 - 0))) * 24 * 3079) / (0.72 * 100,000)) * 0.60

= 78.3 therms

Mid-Life adjustment

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

Efficiency Assumption	System Type	New Baseline Efficiency
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER
ηHeat	Electric Resistance	1.0 COP
	Heat Pump (8.2HSPF/3.413)*0.85	2.04 COP
	Furnace 80% AFUE * 0.85	68% AFUE
	Boiler	84% AFUE

[1180] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[1181] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

[1182] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

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.[1183] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-BINS-V12-220101

REVIEW DEADLINE: 1/1/2025

[1183] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

5.6.3 Floor Insulation Above Crawlspace

DESCRIPTION

Insulation is added to the floor above a vented crawl space that does not contain pipes or HVAC equipment. If there are pipes, HVAC, or a basement, it is desirable to keep them within the conditioned space by insulating the crawl space walls and ground. Insulating the floor separates the conditioned space above from the space below the floor, and is only acceptable when there is nothing underneath that could freeze or would operate less efficiently in an environment resembling the outdoors. Even in the case of an empty, unvented crawl space, it is still considered best practice to seal and insulate the crawl space perimeter rather than the floor. Not only is there generally less area to insulate this way, but there are also moisture control benefits. There is a "Basement Insulation" measure for perimeter sealing and insulation. This measure assumes the insulation is installed above an unvented crawl space and should not be used in other situations.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no insulation on any surface surrounding a crawl space.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1184]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers.[1185] 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

[1184] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1185] 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 capacity market.

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

= 68%[1186]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1187]

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

= 46.6%[1188]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_ heatingElectric + ΔkWh_heatingGas)

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old - 1/(R_added+R_old)) * Area * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool))) * $ADJ_{FloorCool}$ * %Cool

R_old = R-value value of floor before insulation, assuming 3/4" plywood subfloor and carpet with pad

= Actual. If unknown assume 3.53 [1189]

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% [1190]

24 = Converts hours to days

CDD = Cooling Degree Days

1186 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1187 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)'.

1188 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.

1189 Based on 2005 ASHRAE Handbook – Fundamentals: assuming ¾" subfloor, ½" carpet with rubber pad, and accounting for a still air film above and below: 0.68 + 0.94 + 1.23 + 0.68 = 3.53

1190 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[1191]
1 (Rockford)	263
2 (Chicago)	281
3 (Springfield)	436
4 (Belleville)	538
5 (Marion)	570
Weighted Average[1192]	325

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

= 0.75 [1193]

1000 = Converts Btu to kBtu

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

= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1194] or if unknown assume the following:[1195]

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

$ADJ_{FloorCool}$ = Adjustment for cooling savings from floor to account for prescriptive engineering algorithms overclaiming savings[1196]

= 80%

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program	66%

[1191] 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.

[1192] Weighted based on number of occupied residential housing units in each zone.

[1193] Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[1194] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[1195] 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.

[1196] 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%.

Central Cooling?	%Cool
evaluation only)[1197]	

ΔkWh_heatingElectric = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= (((1/R_old - 1/(R_added + R_old)) * Area * (1-Framing_factor) * 24 * HDD)/ (3,412 * ηHeat)) * $ADJ_{FloorHeat}$ *%ElectricHeat

HDD = Heating Degree Days:[1198]

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[1199]	2,895

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1200] or if not available refer to default table below:[1201]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown (for use in program evaluation only)[1202]	N/A	N/A	1.28

1197 Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

1198 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.

1199 Weighted based on number of occupied residential housing units in each zone.

1200 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1201 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.

1202 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration,

$ADJ_{FloorHeat}$ = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings[1203]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[1204], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

Other factors as defined above.

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= ((((1/3.53 -1/(30+3.53))*(20*25)*(1-0.12)* 24 * 281*0.75)/(1000*10.5)) * 0.8 * 1 + (((1/3.53 -1/(30+3.53))*(20*25)*(1-0.15) * 24 * 3079)/(3412*1.92)) * 0.6 * 1)

= (42.9 + 729.1)

= 772 kWh

ΔkWh_heatingGas = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

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

= 3.14%[1205]

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.

1203 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%.

1204 Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

1205 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

> **For example**, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section):
>
> ΔkWh = 68.7 * 0.0314 * 29.3
>
> = 63.2 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location:[1206]

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[1207]	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%[1208]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1209]

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

= 46.6%[1210]

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.

1206 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.

1207 Weighted based on number of occupied residential housing units in each zone.

1208 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1209 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)'.

1210 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:

ΔkW_{SSP} = 42.9 / 570 * 0.68

= 0.051 kW

ΔkW_{SSP} = 42.9 / 570 * 0.466

= 0.035 kW

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms = (((1/R_old - 1/(R_added+R_old)) * Area * (1-Framing_factor) * 24 * HDD) / (100,000 * ηHeat)) * $ADJ_{FloorHeat}$ * %GasHeat

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1211] or if unknown assume 72% for existing system efficiency.[1212]

%GasHeat = Percent of homes that have gas space heating

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[1213], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

Other factors as defined above.

[1211] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[1212] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

[1213] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

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:

$$\Delta Therms = ((1 / 3.53 – 1 /(30 + 3.53))*(20 * 25) * (1 - 0.12) * 24 * 3079) / (100,000 * 0.72) * 0.60 * 1$$

$$= 68.7 \text{ therms}$$

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
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER
ηHeat	Electric Resistance	1.0 COP
	Heat Pump (8.2HSPF/3.413)*0.85	2.04 COP
	Furnace 80% AFUE * 0.85	68% AFUE
	Boiler	84% 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.[1214] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-FINS-V13-220101

REVIEW DEADLINE: 1/1/2025

[1214] 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.

5.6.4 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.[1215]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers.[1216] See section below for detail.

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

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

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

= 68%[1217]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

1215 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

1216 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.

1217 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 72%[1218]

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

= 46.6%[1219]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = ΔkWh_cooling + ΔkWh_heatingElectric + ΔkWh_heatingGas

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to wall insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * CDD * DUA) / (1000 * ηCool)) * $ADJ_{WallCool}$ * %Cool

R_wall = R-value of new wall assembly (including all layers between inside air and outside air).

R_old = R-value value of existing assembly and any existing insulation.

(Minimum of R-5 for uninsulated assemblies)[1220]

A_wall = Net area of insulated wall (ft^2)

Framing_factor_wall = Adjustment to account for area of framing

= 25%[1221]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1222]

Climate Zone (City based upon)	CDD 65
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370
Weighted	947

1218 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)'.
1219 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.
1220 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).
1221 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1
1222 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
Average[1223]	

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

= 0.75 [1224]

1000 = Converts Btu to kBtu

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

= Actual (where new or where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1225] or if unknown assume the following:[1226]

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

$ADJ_{WallCool}$ = Adjustment for cooling savings from wall insulation to account for inaccuracies in prescriptive engineering algorithms[1227]

= 80%

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[1228]	66%

kWh_heatingElectric = If electric heat (resistance or heat pump), reduction in annual electric heating due to wall insulation

= (((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall) * 24 * HDD) / (ηHeat * 3412)) * $ADJ_{WallHeat}$ * %ElectricHeat

[1223] Weighted based on number of occupied residential housing units in each zone.
[1224] 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.
[1225] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).
[1226] 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.
[1227] 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%.
[1228] Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

HDD = Heating Degree Days

= Dependent on location:[1229]

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[1230]	4,860

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1231] or if not available refer to default table below:[1232]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown (for use in program evaluation only)[1233]	N/A	N/A	1.28

3412 = Converts Btu to kWh

$ADJ_{WallHeat}$ = Adjustment for heating savings to account for inaccuracies in prescriptive engineering algorithms.[1234]

[1229] 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.

[1230] Weighted based on number of occupied residential housing units in each zone.

[1231] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[1232] 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.

[1233] 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.

[1234] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[1235], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11, 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((((1/5 - 1/11) * 990 * (1-0.25)) * 842 * 0.75 * 24)/ (1000 * 10.5)) * 80% * 100%) + (((((1/5 - 1/11) * 990 * (1-0.25)) * 5113 * 24) / (1.92 * 3412)) * 60% * 100%)

= 93.5 + 910

= 1,004 kWh

ΔkWh_heatingGas = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

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

= 3.14%[1236]

29.3 = kWh per therm

HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.[1235] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

[1235] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

[1236] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11 with a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section):

ΔkWh_heatingGas = 90.3 * 0.0314 * 29.3

= 83.1 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location as below:[1237]

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[1238]	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%[1239]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%[1240]

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

= 46.6%[1241]

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11, 10.5 SEER Central AC, and 2.26 COP Heat Pump:

ΔkW_{SSP} = 93.5 / 570 * 0.68

= 0.11 kW

ΔkW_{PJM} = 93.5 / 570 * 0.466

= 0.08 kW

1237 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.

1238 Weighted based on number of occupied residential housing units in each zone.

1239 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1240 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)'.

1241 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms = (((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall) * 24 * HDD) / (ηHeat * 100,000 Btu/therm)) * $ADJ_{WallHeat}$* %GasHeat

Where:

HDD = Heating Degree Days

= Dependent on location:[1242]

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[1243]	4,860

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available).[1244] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1245] or if unknown assume 72% for existing system efficiency.[1246]

%GasHeat = Percent of homes that have gas space heating

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[1247], use the following table:

1242 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.

1243 Weighted based on number of occupied residential housing units in each zone.

1244 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.

1245 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1246 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

1247 Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

Other factors as defined above.

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11, with a gas furnace with system efficiency of 66%:

ΔTherms = ((((1/5 - 1/11) * 990 * (1-0.25)) * 24 * 5113) / (0.66 * 100,000)) * 60% * 100%

= 90.4 therms

Mid-Life adjustment

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

Efficiency Assumption	System Type	New Baseline Efficiency
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER
ηHeat	Electric Resistance	1.0 COP
	Heat Pump (8.2HSPF/3.413)*0.85	2.04 COP
	Furnace 80% AFUE * 0.85	68% AFUE
	Boiler	84% 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.[1248] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[1248] 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-SHL-WINS-V11-220101

REVIEW DEADLINE: 1/1/2024

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.[1249]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers.[1250] See section below for detail.

Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

Loadshape

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

Coincidence Factor

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

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

= 68%[1251]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

[1249] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1250] 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.

[1251] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 72%[1252]

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

= 46.6%[1253]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heatingElectric + ΔkWh_heatingGas)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to celing/attic insulation

= ((((1/R_old - 1/R_attic) * A_attic * (1-Framing_factor_attic)) * 24 * CDD * DUA) / (1000 * ηCool)) * $ADJ_{AtticCool}$ * $IE_{NetCorrection}$ * %Cool

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

R_old = R-value value of existing assembly and any existing insulation.

(Minimum of R-3 for uninsulated assemblies)[1254]

A_attic = Total area of insulated ceiling/attic (ft^2)

Framing_factor_attic = Adjustment to account for area of framing

= 7%[1255]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1256]

Climate Zone (City based upon)	CDD 65
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370
Weighted Average[1257]	947

[1252] 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)'.
[1253] 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.
[1254] Component estimate of airfilm above and below, sheathing and sheet rock, (0.68+0.5+0.45+0.68 = 2.3) is rounded up to R-3.
[1255] Ibid.
[1256] 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.
[1257] Weighted based on number of occupied residential housing units in each zone.

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

= 0.75 [1258]

1000 = Converts Btu to kBtu

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

= Actual (where new or where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1259] or if unknown assume the following:[1260]

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

$ADJ_{AtticCool}$ = Adjustment for cooling savings to account for inaccuracies in engineering algorithms[1261]

= 121%

$IE_{NetCorrection}$ = 100% if not income eligible or attic insulation is installed without air sealing

= 110% if installing air sealing and attic insulation in income eligible projects with a deemed NTG value of 1.0 to offset net savings adjustment inherent when using $ADJ_{AtticCool}$ of 121%[1262]

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program	66%

1258 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.

1259 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1260 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.

1261 As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. Adjustment factor was derived from a consumption data regression analysis with an experimental design that does not require further net savings adjustment for non-income eligible populations.

1262 The additional value of 10% was selected to acknowledge that some portion of the regression-derived adjustment factors accounts for gross impact effects, and that removing net effects embedded in the adjustment factors would increase savings to some degree. A review of historical NTG values for air sealing and insulation measures in non-income eligible populations did not provide definitive guidance for estimating the net component of the adjustment factors. Historically, free ridership has ranged from 9% to 26% for like measures, and spillover has ranged from 1% to 14%, while NTGs have ranged from 0.75 to 1.05. The midpoint of the NTG range would be 0.90, a 10% reduction from 1.0.

Central Cooling?	%Cool
evaluation only)[1263]	

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

= ((((1/R_old - 1/R_attic) * A_attic * (1-Framing_factor_attic)) * 24 * HDD) / (ηHeat * 3412)) * $ADJ_{AtticElectricHeat}$*%ElectricHeat

HDD = Heating Degree Days

= Dependent on location:[1264]

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[1265]	4,860

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1266] or if not available refer to default table below:[1267]

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

1263 Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

1264 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.

1265 Weighted based on number of occupied residential housing units in each zone.

1266 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1267 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85
only)[1268]			

3412 = Converts Btu to kWh

$ADJ_{AtticElectricHeat}$ = Adjustment for electric heating savings to account for inaccuracies in engineering algorithms[1269]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[1270], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

1268 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.

1269 As demonstrated in air sealing and insulation research by Navigant, Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

1270 Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

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

Assume a non-income eligible single family home in Chicago installs 700 ft^2 of attic insulation, completes air sealing, has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

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

= 197 + 1,271

= 1,468 kWh

ΔkWh_heatingGas = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3 * $ADJ_{AtticHeatFan}$

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

= 3.14%[1271]

29.3 = kWh per therm

$ADJ_{AtticHeatFan}$ = Adjustment for fan savings to account for innacuracies in engineering algorithms[1272]

= 107%

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

Assume a non-income eligible single family home in Chicago installs 700 ft^2 of attic insulation, completes air sealing, has a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section), and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔkWh = 147 * 0.0314 * 29.3 * 107%

= 145 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location as below:[1273]

[1271] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[1272] As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. Adjustment factor was derived from a consumption data regression analysis with an experimental design that does not require further net savings adjustment for non-income eligible populations.

[1273] 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)	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[1274]	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%[1275]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%[1276]

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

= 46.6%[1277]

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

Assume a non-income eligible single family home in Chicago installs 700 ft^2 of attic insulation, has 10.5 SEER Central AC and 2.26 COP Heat Pump, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔkW_{SSP} = 197 / 570 * 0.68

= 0.24 kW

ΔkW_{PJM} = 168 / 570 * 0.466

= 0.16 kW

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms = ((((1/R_old - 1/R_attic) * A_attic * (1-Framing_factor_attic)) * 24 * HDD) / (ηHeat * 100,000 Btu/therm) * $ADJ_{AtticGasHeat}$ * $IE_{NetCorrection}$ * %GasHeat

Where:

HDD = Heating Degree Days

= Dependent on location:[1278]

[1274] Weighted based on number of occupied residential housing units in each zone.
[1275] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[1276] 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)'.
[1277] 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.
[1278] 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
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438
Weighted Average[1279]	4,860

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available).[1280] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1281] or if not available, use 72% for existing system efficiency.[1282]

$ADJ_{AtticGasHeat}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms[1283]

= 72%

$IE_{NetCorrection}$ = 100% if not income eligible or attic insulation is installed without air sealing

= 110% if installing air sealing and attic insulation in income eligible projects with a deemed NTG value of 1.0 to offset net savings adjustment inherent when using $ADJ_{AtticGasHeat}$ of 72% [1284]

%GasHeat = Percent of homes that have gas space heating

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[1285], use the following table:

1279 Weighted based on number of occupied residential housing units in each zone.

1280 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.

1281 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1282 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

1283 As demonstrated in air sealing and insulation research by Navigant, Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. Adjustment factor was derived from a consumption data regression analysis with an experimental design that does not require further net savings adjustment for non-income eligible populations.

1284 The additional value of 10% was selected to acknowledge that some portion of the regression-derived adjustment factors accounts for gross impact effects, and that removing net effects embedded in the adjustment factors would increase savings to some degree. A review of historical NTG values for air sealing and insulation measures in non-income eligible populations did not provide definitive guidance for estimating the net component of the adjustment factors. Historically, free ridership has ranged from 9% to 26% for like measures, and spillover has ranged from 1% to 14%, while NTGs have ranged from 0.75 to 1.05. The midpoint of the NTG range would be 0.90, a 10% reduction from 1.0.

1285 Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

Other factors as defined above.

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

Assume a non-income eligible single family home in Chicago installs 700 ft^2 of attic insulation, has a gas furnace with system efficiency of 66%, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

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

= 151 therms

Mid-Life adjustment

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

Efficiency Assumption	System Type	New Baseline Efficiency
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER
ηHeat	Electric Resistance	1.0 COP
	Heat Pump (8.2HSPF/3.413)*0.85	2.04 COP
	Furnace 80% AFUE * 0.85	68% AFUE
	Boiler	84% 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.[1286] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

1286 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.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AINS-V05-220101

REVIEW DEADLINE: 1/1/2025

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.[1287]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers[1288]. See section below for detail.

Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

Loadshape

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

Coincidence Factor

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

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

= 68%[1289]

[1287] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1288] 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.

[1289] 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%[1290]

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

= 46.6%[1291]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_ heatingElectric + ΔkWh_heatingGas)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * CDD * 24 * DUA * ADJ_{BasementCool*\%Cool}}{(1000 * \eta Cool)}$$

R_{Rim} = R-value of new rim/band joist assembly (including all layers between inside air and outside air).

R_{old} = R-value value of existing assembly and any existing insulation.

(Minimum of R-5 for uninsulated assemblies)[1292]

A_{Rim} = Net area of insulated rim/band joist (ft^2)

$FramingFactor_{Rim}$ = Adjustment to account for area of framing

= 5%[1293]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1294]

[1290] 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)'.
[1291] 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.
[1292] 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).
[1293] 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.
[1294] 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)	Conditioned CDD 65	Unconditioned CDD 75[1295]
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[1296]	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 [1297]

1000 = Converts Btu to kBtu

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

= Actual (where new or where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1298] or if unknown assume the following:[1299]

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

$ADJ_{BasementCool}$ = Adjustment for cooling savings from basement wall and rim/band joist insulation to account for prescriptive engineering algorithms overclaiming savings[1300]

= 80%

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program	66%

1295 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.

1296 Weighted based on number of occupied residential housing units in each zone.

1297 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.

1298 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1299 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.

1300 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%.

Central Cooling?	%Cool
evaluation only)[1301]	

kWh_heatingElectric = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJ_{BasementHeat} * \%ElectricHeat}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:[1302]

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[1303]	4,860	2,895

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1304] or if not available, refer to default table below:[1305]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown (for use in program evaluation only)[1306]	N/A	N/A	1.28

[1301] Percentage of homes in Illinois that have central cooling from "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009" from Energy Information Administration, 2009 Residential Energy Consumption Survey

[1302] 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.

[1303] Weighted based on number of occupied residential housing units in each zone.

[1304] Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[1305] 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.

[1306] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration,

3412 = Converts Btu to kWh

$ADJ_{BasementHeat}$ = Adjustment for basement wall and rim/band joist insulation to account for prescriptive engineering algorithms overclaiming savings[1307]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[1308], use the following table:

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	18%	26%	38%	39%	29%
ComEd	14%	22%	43%	48%	21%
PGL	16%	22%	40%	50%	31%
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

For example, a single family home in Chicago with 100 ft^2 of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((1/5 - 1/13) * 100 * (1-0.05) * 281 * 24 * 0.75 * 1) / (1000 * 10.5)) + (((1/5 - 1/13) * 100 * (1-0.05) * 3079 * 24 * 0.60 * 1) / (1.92 * 3412))

= 5.6 + 79.1

= 84.7 kWh

ΔkWh_heatingGas = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

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.

[1307] 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%.

[1308] Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

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

= 3.14%[1309]

29.3 = kWh per therm

For example, a single family home in Chicago with 100 ft^2 of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section):

ΔkWh = 7.85 * 0.0314 * 29.3

= 7.2 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location as below:[1310]

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[1311]	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%[1312]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%[1313]

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

= 46.6%[1314]

1309 F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

1310 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.

1311 Weighted based on number of occupied residential housing units in each zone.

1312 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1313 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)'.

1314 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 100 ft^2 of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkW_{SSP} = 5.6 / 570 * 0.68

= 0.0067 kW

ΔkW_{PJM} = 5.6 / 570 * 0.466

= 0.0046 kW

NATURAL GAS SAVINGS

If Natural Gas heating:

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJ_{BasementHeat} * \%GasHeat}{(\eta Heat * 100{,}000)}$$

Where:

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available).[1315] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1316] or if not available, use 72% for existing system efficiency.[1317]

%GasHeat = Percent of homes that have gas space heating

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[1318], use the following table:

1315 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.

1316 Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

1317 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

1318 Based on the average % Natural Gas used for space heating in Unknown residential structure types across all utilities covered by the IL program. Residence types include: SF, SF LI, MF & MF LI. Utilities included: Ameren, ComEd, People's Gas, Northshore Gas & Nicor. Data provided from 2016 Ameren Illinois Demand Side Management (DSM) Market Potential Study by Applied Energy Group, ComEd's 2019 Baseline Survey on residential space heating share, and Peoples & Northshore Gas potential study of end use saturations.

Utility	Residence Type				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren	82%	74%	62%	61%	71%
ComEd	86%	78%	57%	52%	79%
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

Other factors as defined above.

For example, a single family home in Chicago with 100 ft^2 of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 66%:

ΔTherms = ((1/5 - 1/13) * 100 * (1-0.05) * 3079 * 24 * 0.60 * 1) / (0.66 * 100,000)

= 7.85 therms

Mid-Life adjustment

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

Efficiency Assumption	System Type	New Baseline Efficiency
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER
ηHeat	Electric Resistance	1.0 COP
	Heat Pump (8.2HSPF/3.413)*0.85	2.04 COP
	Furnace 80% AFUE * 0.85	68% AFUE
	Boiler	84% 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.[1319] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[1319] 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-SHL-RINS-V04-220101

REVIEW DEADLINE: 1/1/2025

5.6.7 Low-E Storm Window

DESCRIPTION

Emissivity is a measure of thermal radiation emitted by an object's surface. Emissivity values range from 0 to 1 with 1 being the emissivity of a black body. Low emissivity (low-e) storm window inserts reduce the rate of thermal radiation of the window assembly through the interaction of multiple properties. The low-e surface of the insert means that the window will transfer heat at a reduced rate. The newly created air gap between the window and the insert combined with the low emissivity of the insert improves thermal performance of the window assembly. The inserts include weather-stripping as a means of sealing the connection which reduces air infiltration. This measure offers benefits during both heating and cooling seasons, for both natural gas and electricity. In addition to energy benefits, this measure offers non-energy benefits including increased comfort and noise reduction.

The calculation of savings presented in this section apply to single and multifamily residential applications with no portable window air conditioners. Small commercial applications with operating characteristics similar to a residential profile are also eligible for the savings presented here.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is a window insert installed over either the interior or exterior of the baseline window. The insert must be ENERGY STAR certified and meet the ENERGY STAR storm windows key product criteria.

ENERGY STAR key product criteria for storm windows[1320]

<table>
<tr><th>Climate Zone</th><th>Emissivity</th><th>Solar Transmission</th></tr>
<tr><td>1 - Rockford</td><td rowspan="5">≤ 0.22</td><td rowspan="3">> 0.55</td></tr>
<tr><td>2 - Chicago</td></tr>
<tr><td>3 - Springfield</td></tr>
<tr><td>4 - Belleville</td><td rowspan="2">Any</td></tr>
<tr><td>5 – Marion</td></tr>
</table>

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is an existing single-pane or double-pane window with clear glass and any frame type: metal, vinyl, or wood.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 20 years.[1321]

DEEMED MEASURE COST

The incremental cost for this measure is $7.85 per square foot material cost. Applications using professional window installers should include an additional $30 per window installation cost.[1322]

LOADSHAPE

Loadshape R08 - Residential Cooling

[1320] ENERGY STAR Storm Windows Key Product Criteria, accessed February 2020.
[1321] Pacific Northwest National Laboratory for the U.S. Department of Energy, "Task ET-WIN-PNNL-FY13-01-5.3: Database of Low-e Storm Window Energy Performance across U.S. Climate Zones," September 2013: page 5.
[1322] Ibid.

Loadshape R09 - Residential Electric Space Heat
Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

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

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

= 68%[1323]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1324]

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

= 46.6%[1325]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heatingElectric} + \Delta kWh_{heatingGas}$$

$$\Delta kWh_{cooling} = CS_{cz} * Area_{window}$$

$$\Delta kWh_{heatingElectric} = EHS_{cz} * Area_{window}$$

$$\Delta kWh_{heatingGas} = \Delta Therms * F_e * 29.3$$

Where:

CS_{cz} = Annual cooling savings per area of window by climate zone, see table below.

Cooling savings per window area by climate zone and baseline window condition[1326]

[1323] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[1324] 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)'.
[1325] 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.
[1326] Based on savings modeled by EPA, "ES Storm Windows RESFEN Data and Calculations.xlsx", April 2017. Whole House Cooling energy values from the "Raw Data-Exterior Storm Windows" and "Raw Data-Interior Storm Windows," Climate Zone 5, Location IL Chicago, wood frame, single pane, exterior low-E (0.148 panel) and interior low-E (0.148 panel) were used to calculated savings. EPA only reported single pane modeling results. In order to estimate impacts for double pane windows, ratios of double pane to single pane cooling energy was applied as reported by the Pacific Northwest National Laboratory for the U.S. Department of Energy, "Task ET-WIN-PNNL-FY13-01-5.3: Database of Low-e Storm Window Energy Performance across U.S. Climate Zones," September 2013. Values from Appendix C, table C.8 for Chicago, Illinois were used to calculate the ratio of double pane to single pane cooling energy. See "Low E Window Workpaper Supporting Calculations.xlsx" for reference. The was data modified for different heating zones of Illinois.

Climate Zone	Single Pane Base Window (kWh/ft^2)	Double Pane Base Window (kWh/ft^2)
1 - Rockford	0.46	0.33
2 - Chicago	0.47	0.34
3 - Springfield	0.62	0.45
4 - Belleville	0.88	0.64
5 - Marion	0.77	0.56

EHS_{cz} = Annual electric heating savings per area of window by climate zone, see table below

Heating savings per window area by climate zone, heating type, and baseline window condition[1327]

	Electric Resistance Heat		Electric Heat Pump	
Climate Zone	Single Pane Base Window (kWh/ft^2)	Double Pane Base Window (kWh/ft^2)	Single Pane Base Window (kWh/ft^2)	Double Pane Base Window (kWh/ft^2)
1 - Rockford	16.84	1.90	9.31	1.05
2 - Chicago	16.09	1.81	8.89	1.00
3 - Springfield	13.78	1.55	7.61	0.86
4 - Belleville	10.63	1.20	5.87	0.66
5 - Marion	10.82	1.22	5.98	0.67

$Area_{window}$ = Total area of installed window inserts. Use site specific value.

$\Delta Therms$ = Therm savings from gas heating as calculated below

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption, 3.14%[1328]

29.3 = Conversion factor, kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\frac{\Delta kWh_{cooling}}{FLH_{cooling}}\right) * CF$$

Where:

[1327] Based on savings modeled by EPA, "ES Storm Windows RESFEN Data and Calculations.xlsx", April 2017. Whole House Heating energy values from the "Raw Data-Exterior Storm Windows" and "Raw Data-Interior Storm Windows," Climate Zone 5, Location IL Chicago, wood frame, single pane, exterior low-E (0.148 panel) and interior low-E (0.148 panel) were used to calculated savings. EPA only reported single pane modeling results. In order to estimate impacts for double pane windows, ratios of double pane to single pane cooling energy was applied as reported by the Pacific Northwest National Laboratory for the U.S. Department of Energy, "Task ET-WIN-PNNL-FY13-01-5.3: Database of Low-e Storm Window Energy Performance across U.S. Climate Zones," September 2013. Values from Appendix C, table C.8 for Chicago, Illinois were used to calculate the ratio of double pane to single pane heating energy. See "Low E Window Workpaper Supporting Calculations.xlsx" for reference. To convert from "Furnace" savings to electric, it is assumed a furnace efficiency of 72%, electric resistance of 100% and heat pump of 1.81 (average of pre-2006 and 2006-2014 federal standard).

[1328] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

$FLH_{cooling}$ = Full load hours of air conditioning based on climate zone.

= Dependent on location:[1329]

Climate Zone	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 utility peak hour)

= 68%[1330]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1331]

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

= 46.6%[1332]

NATURAL GAS SAVINGS

$$\Delta Therms = GHS_{cz} * Area_{window}$$

Where:

GHS_{cz} = Annual gas heating savings per area of window by climate zone, see table below

Heating savings per window area by climate zone and baseline window condition[1333]

Climate Zone	Single Pane Base Window (therms/ft^2)	Double Pane Base Window (therms/ft^2)
1 - Rockford	0.80	0.09
2 - Chicago	0.76	0.09
3 - Springfield	0.65	0.07
4 - Belleville	0.50	0.06
5 - Marion	0.51	0.06

1329 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.

1330 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1331 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)'.

1332 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.

1333 Based on savings modeled by EPA, "ES Storm Windows RESFEN Data and Calculations.xlsx", April 2017. Whole House Heating energy values from the "Raw Data-Exterior Storm Windows" and "Raw Data-Interior Storm Windows," Climate Zone 5, Location IL Chicago, wood frame, single pane, exterior low-E (0.148 panel) and interior low-E (0.148 panel) were used to calculated savings. EPA only reported single pane modeling results. In order to estimate impacts for double pane windows, ratios of double pane to single pane cooling energy was applied as reported by the Pacific Northwest National Laboratory for the U.S. Department of Energy, "Task ET-WIN-PNNL-FY13-01-5.3: Database of Low-e Storm Window Energy Performance across U.S. Climate Zones," September 2013. Values from Appendix C, table C.8 for Chicago, Illinois were used to calculate the ratio of double pane to single pane heating energy. See "Low E Window Workpaper Supporting Calculations.xlsx" for reference.

$Area_{window}$ = Total area of installed window inserts. Use site specific value.

For example, a single family gas heated residence in Rockford installs 10 window inserts over single pane windows. Each window is 12 square feet for a total window area of 120 square feet.

$$\Delta Therms = 0.80 * 120 = 95.81 \; therms$$

$$\Delta kWh = 0.46 * 120 + 95.81 * 0.0314 * 29.3 = 143.37 \; kWh$$

$$\Delta kW_{PJM} = \left(\frac{143.37}{512}\right) * 0.466 = 0.13 \; kW$$

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-LESW-V01-210101

REVIEW DEADLINE: 1/1/2024

5.6.8 Triple Pane and Thin Triple Windows

DESCRIPTION

Conventional triple pane windows and thin triple windows (TTW) greatly improve building thermal envelope performance compared to code standard double-glazed windows. High performance windows must achieve a U-value ≤ 0.20 (R5) to meet the criteria of this measure marking a significant improvement from Illinois' most stringent climate zone, which requires a U-value ≤ 0.30 (R-3.3). High performance windows significantly decrease heat loss through the buildings envelope by adding a third pane of glass in the insulating glass unit (IGU). This provides an additional surface to include another low-E coating and increases resistance to heat loss by improving the insulating capability of the window.

The window's reduced heat loss has a significant impact on home energy savings as windows are often the weakest part of any building envelope. In addition to reducing heat loss, TTW also reduce air infiltration contributing to decreased HVAC loads. These products provide benefits for both heating and cooling seasongs and for both natural gas and electric heated and cooled homes. They also have non-energy benefits such as, increased thermal comfort and decreased outside noise.

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

DEFINITION OF EFFICIENT EQUIPMENT

Window containing triple-pane IGU that meets the performance specifications below

Table 1: Key Product Criteria for High Performance Windows[1334]

Climate Zone	U-Value	SHGC
1 - Rockford	≤ 0.20	≥ 0.30
2 – Chicago		
3 – Springfield		
4 – Belleville		
5 – Marion		

- Thin Triple Windows (TTW) – the insulating glass unit (IGU) contains three panes of glass - a thin pane of center glass allows the IGU to fit within a standard window frame, eliminating the need to redesign the window. The inclusion of a thin pane of center glass allows for an additional surface for low-E coating, reducing the windows emissivity of thermal radiation and the rate of heat transfer by improving the U-value of the IGU and overall assembly. Thin triple windows will have two equal width panes of glass on the exterior of the IGU and a thin center piece of glass that allows the IGU to fit within an existing double-pane window frame.

- Triple Pane Windows – conventional triple pane windows contain three panes of standard thickness glass. These windows provide an additional surface for a low-e coating and provide improved thermal performance by decreasing the windows emissivity and improving the window's resistance to heat loss. These windows are typically heavier than double-pane or TTW and require a redesign of the window to allow the heavier, wider IGU to fit within the window frame.

DEFINITION OF BASELINE EQUIPMENT

New Construction and Time of Sale: IL code minimum windows according to the table below

[1334] Modeled savings developed by Robert Hart, Berkeley National Lab – "High Performance Windows - Illinois Modeled Savings Summary", April 2021.

Table 2: Illinois Code - Window Values[1335]

Climate Zone	U-Value	SHGC
1 - Rockford	≤ 0.30	*Not Rated*
2 – Chicago		
3 – Springfield		
4 – Belleville	≤ 0.32	≥ 0.40
5 – Marion		

Early Replacement in Existing Homes:

Table 3: Existing Homes – Existing Window Values[1336]

Climate Zone	U-Value	SHGC
1 - Rockford	0.55	0.63
2 – Chicago		
3 – Springfield		
4 – Belleville		
5 – Marion		

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 40 years[1337]

Remaining life of existing equipment – 13 years[1338]

Deemed Measure Cost

New Construction and Time of Sale: The incremental installed cost (window cost plus installation cost) for this measure depends on the window type as listed below:

Triple Glazed Windows[1339] – $\$3.13/ft^2$

The incremental cost of triple glazed windows accounts for increased material and installation costs.

Thin Triple Pane Windows[1340] - $\$2.30/ft^2$

The incremental cost associated with this measure pertains only to material cost, as installation is the same as double-pane windows.

Early Replacement: The full installed cost is based on window type below. The assumed deferred cost (after 13 years)

1335 Illinois Energy Conservation Code, July 1, 2018. TABLE R402.1.2, pg 7. Please see file : *2018 Illinois Specific Amendments with Modifications Shown.pdf. Link :* https://www2.illinois.gov/cdb/business/codes/IllinoisAccessibilityCode/Documents/2018%20Illinois%20Specific%20Amendments%20with%20Modifications%20Shown.pdf

1336 Engineering judgement, modeled savings developed by Robert Hart, Berkeley National Lab – "High Performance Windows - Illinois Modeled Savings Summary", April 2021. Informed by 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.

1337 The Northwest Power Plan (NPCC). Please see sheet "Source Summary" within file: Com-Windows-2021P_V17.xlsx. Link: https://nwcouncil.app.box.com/s/u0dgjxkoxoj2tttym81uka3wrjcy6bo6/file/655810989510

1338 Assumed to be one third of effective useful life. For future TRM versions, recommend RUL be informed from program research.

1339 Gilbride, Selkowtiz, Dingus, Cort – "Double or Triple? Factors Influencing the Window Purchasing Decisions of High-Performance Home Builders" July 2019. https://www.osti.gov/biblio/1557862-double-triple-factors-influencing-window-purchasing-decisions-high-performance-home-builders

1340 Selkowitz, Hart, Curcija: Breaking the 20 Year Logjam to Better Insulating Windows – September 2018 https://eta-publications.lbl.gov/sites/default/files/selkowitz_breaking_the_20_year_logjam.pdf of replacing existing windows with a new code required double-pane baseline unit is assumed to be $48.50 per square foot[1341].

Thin Triple Pane Windows[1342] - $50.80/ft^2

Triple Glazed Windows[1343] – $51.63/ft^2

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%[1344]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour) = 72%[1345]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period) = 46.6%[1346]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan}$$

$$\Delta kWh = CS_{cz} * Area_{window}$$

Where:

CS_{cz} = Annual heating, cooling + fan savings per area of window by climate zone, see Tables 4 & 5 below.

1341 $37.82 inflated using 1.91% rate.

1342 Selkowitz, Hart, Curcija: Breaking the 20 Year Logjam to Better Insulating Windows – September 2018 https://eta-publications.lbl.gov/sites/default/files/selkowitz_breaking_the_20_year_logjam.pdf

1343 Gilbride, Selkowtiz, Dingus, Cort – "Double or Triple? Factors Influencing the Window Purchasing Decisions of High-Performance Home Builders" July 2019 https://www.osti.gov/biblio/1557862-double-triple-factors-influencing-window-purchasing-decisions-high-performance-home-builders

1344 The coincidence factors are the same as other shell measures in the IL TRM. For detail on this coincidence factor please see the reference for the coincidence factors in the Air Sealing measure.
"Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory."

1345 The coincidence factors are the same as other shell measures in the IL TRM. For detail on this coincidence factor please see the reference for the coincidence factors in the Air Sealing measure. "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)'."

1346 The coincidence factors are the same as other shell measures in the IL TRM. For detail on this coincidence factor please see the reference for the coincidence factors in the Air Sealing measure.
"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."

$Area_{window}$ = Total area of installed high performance windows. Use site specific value.

Table 4: Gas Furnace and Air Conditioner - savings per window area by climate zone and baseline window condition[1347]

Climate Zone	New Construction or Time of Sale (kWh/ft^2)	Early Replacement (kWh/ft^2)
1 – Rockford	0.55	1.28
2 – Chicago	0.55	1.24
3 – Springfield	0.62	1.47
4 – Belleville	0.56	1.44
5 – Marion	0.51	1.42

Table 5: Electric Resistance Heat with AC or Heat Pump - savings per window area by climate zone and baseline window condition[1348]

	Electric Resistance Heat + AC		Electric Heat Pump	
Climate Zone	New Construction or Time of Sale (kWh/ft^2)	Early Replacement (kWh/ft^2)	New Construction or Time of Sale (kWh/ft^2)	Early Replacement (kWh/ft^2)
1 – Rockford	3.22	9.26	2.04	9.37
2 – Chicago	2.95	8.27	1.75	8.26
3 – Springfield	2.63	7.22	1.59	7.48
4 – Belleville	3.16	6.99	1.90	7.04
5 – Marion	2.71	5.92	1.52	5.99

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\frac{\Delta kWh_{cooling}}{FLH_{cooling}}\right) * CF$$

Where:

$FLH_{cooling}$ = Full load hours of air conditioning based on climate zone, see Table 6.

Table 6: Full load cooling hours by climate zone. [1349]

Climate Zone	Single Family	Multifamily
1 – Rockford	512	467
2 – Chicago	570	506
3 – Springfield	730	663
4 – Belleville	1,035	940
5 – Marion	903	820

1347 EnergyPlus models were used to develop the savings per Hart 2018 paper methods and assumptions, Illinois Savings Summary

1348 Ibid

1349 The determination of full load cooling hours is the same as other shell measures in the IL TRM. For detail on this input please see the reference for FLH in the Air Sealing measure.
"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."

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour) = 68%[1350]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour) = 72%[1351]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period) = 46.6%[1352]

NATURAL GAS SAVINGS

$$\Delta Therms = HS_{cz} * Area_{window}$$

Where:

HS_{cz} = Annual heating savings per area of window by climate zone, see Table 7.

$Area_{window}$ = Total area of installed high performance windows. Use site specific value.

Table 7: Heating savings per window area by climate zone and baseline window condition

Climate Zone	New Construction or Time of Sale (therm/ft^2)	Early Replacement (therm/ft^2)
1 – Rockford	0.11	0.35
2 – Chicago	0.10	0.31
3 – Springfield	0.09	0.24
4 – Belleville	0.11	0.23
5 – Marion	0.09	0.19

For example, a single family residence in Rockford with a gas furnace and air conditioner replaces 10 existing windows with Thin Triple windows. Each window is 12 square feet for a total window area of 120 square feet.

1st 13 years savings calculation:

$$\Delta Therms = 0.35 * 120 = 42\ therms$$

$$\Delta kWh = 1.28 * 120 = 153.6\ kWh$$

$$\Delta kW_{PJM} = \left(\frac{153.6}{512}\right) * 0.466 = 0.14\ kW$$

Remaining 27 years savings calculation:

$$\Delta Therms = 0.11 * 120 = 13.2\ therms$$

$$\Delta kWh = 0.55 * 120 = 66\ kWh$$

$$\Delta kW_{PJM} = \left(\frac{66}{512}\right) * 0.466 = 0.129\ kW$$

1350 The coincidence factors are the same as other shell measures in the IL TRM. For detail on this coincidence factor please see the reference for the coincidence factors in the Air Sealing measure.
"Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory."

1351 The coincidence factors are the same as other shell measures in the IL TRM. For detail on this coincidence factor please see the reference for the coincidence factors in the Air Sealing measure.
"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)'."

1352 The coincidence factors are the same as other shell measures in the IL TRM. For detail on this coincidence factor please see the reference for the coincidence factors in the Air Sealing measure.
"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-SHL-TTWI-V01-220101

Review Deadline: 1/1/2024

5.7 Miscellaneous

5.7.1 High Efficiency Pool Pumps

DESCRIPTION

Residential outdoor pool pumps can be single speed, two/multi speed or variable speed. A federal standard (82 FR 5650) effective July 19, 2021 effectively requires new pumps to be at least two speed.

Single speed pumps are 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%.[1353]

This measure is the characterization of the purchasing and installing of a new ENERGY STAR or CEE T1 variable speed residential pool pump motor in place of a new baseline pump meeting the federal standard for Time of Sale and New Construction, or the early replacement of a standard single speed motor of equivalent horsepower.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is an ENERGY STAR or CEE Tier residential pool pump meeting the ENERGY STAR minimum qualifications for either in-ground or above ground pools. ENERGY STAR version 3.0 specification takes effect on July 19, 2021. Note that for in ground pools, the CEE T1 level is the same as the new Federal Standard, and Tier 2 is the same as ENERGY STAR V3 for the standard size pumps, so savings for CEE T1 is only provided for above ground pools where there is an increment in efficiency.

Pump Sub-Type	Size Class	ENERGY STAR Version 3.0 Energy Efficiency Level (Effective 7/19/2021)	CEE Tier 1	CEE Tier 2
Self-Priming (Inground) Pool Pumps	Extra Small (hhp ≤ 0.13)	WEF ≥ 13.40	N/A	N/A
	Small (hhp > 0.13 and < 0.711)	WEF ≥ -2.45 x ln (hhp) + 8.40	WEF ≥ -1.30 x ln (hhp) + 4.95	WEF ≥ -2.83 x ln (hhp) + 8.84
	Standard Size (hhp ≥ 0.711)	WEF ≥ -2.45 x ln (hhp) + 8.40	WEF ≥ -2.3 x ln (hhp) + 6.59	WEF ≥ -2.45 x ln (hhp) + 8.4
Non-Self Priming (Aboveground) Pool Pumps	Extra Small (hhp ≤ 0.13)	WEF ≥ 4.92	N/A	N/A
	Standard Size (hhp > 0.13)	WEF ≥ -1.00 x ln (hhp) + 3.85	WEF ≥ -1.60 x ln (hhp) + 9.10	N/A

DEFINITION OF BASELINE EQUIPMENT

For TOS and NC, the baseline equipment is a two speed residential pool pump meeting the Federal Standard, effective July 19, 2021 provided below:

[1353] U.S. DOE, 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. Report No. DOE/GO-102012-3534.

Pump Sub-Type	Size Class	Baseline (Effective 7/19/2021)
Self-Priming (Inground) Pool Pumps	Extra Small (hhp ≤ 0.13)	WEF ≥ 5.55
	Small (hhp > 0.13 and < 0.711)	WEF ≥ -1.30 x ln (hhp) + 2.90
	Standard Size (hhp ≥ 0.711)	WEF ≥ -2.30 x ln (hhp) + 6.59
Non-Self Priming (Aboveground) Pool Pumps	Extra Small (hhp ≤ 0.13)	WEF ≥ 4.60
	Standard Size (hhp > 0.13)	WEF ≥ -0.85 x ln (hhp) + 2.87

For early replacement, the baseline equipment is the existing single speed residential pool pump.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for a two speed or variable speed pool pump is 7 years.[1354]

DEEMED MEASURE COST

For TOS and NC, the incremental costs for ENERGY STAR in-ground pool pumps are estimated as $314[1355] and for above ground pool pumps are estimated as $930.[1356]

For early replacement, the full replacement costs shall be used. A deferred new baseline cost (after 4 years) of replacing the existing equipment should also be included.

LOADSHAPE

Loadshape R15 – Residential Pool Pumps

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.831.[1357]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS[1358]

For TOS and NC:

$\Delta kWh = (Gallons * Turnovers * (1/WEF_{base} - 1/WEF_{ESTAR}) * Days) / 1000$

For Early Replacement:

$\Delta kWh = (Gallons * Turnovers * (1/EF_{Exist} - 1/WEF_{ESTAR}) * Days) / 1000$

1354 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
1355 ENERGY STAR Pool Pump Calculator and represent the difference between the two/multi speed incremental cost and the variable speed incremental cost.
1356 CEE Efficient Residential Swimming Pool Initiative, December 2012, page 18 and represent the difference between the two/multi speed incremental cost and the variable speed incremental cost.
1357 Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.
1358 The methodology followed is consistent with the most recent version of the 2020 ENERGY STAR calculator (Pool_Pump_Calculator_2020.05.05_FINAL.xls), however this has not been updated to account for the new federal standard.

Where:

Gallons = Capacity of the pool

= Actual. If unknown assume:

Pool Type	Gallons
In ground	22,000[1359]
Above ground	7,540[1360]

Turnovers = Desired number of pool water turnovers per day

= 2[1361]

WEF_{base} = Weighted Energy Factor of baseline pump (gal/Wh) [1362]

Pool Type	WEF_{Base}
In ground	4.6
Above ground	2.6

WEF_{ESTAR} = Weighted Energy Factor of ENERGY STAR pump (gal/Wh) [1363]

Pool Type	WEF_{EE}	
	ENERGY STAR	CEE Tier 1
In ground	6.31	N/A
Above ground	3.49	8.53

EF_{Exist} = Energy Factor of existing single speed pump (gal/Wh)

= 2.3[1364]

Days = Number of days per year that the swimming pool is operational

= 122[1365]

1,000 = Conversion factor from Wh to kWh

Based on the defaults provided above, the annual energy savings (ΔkWh) are detailed in the table below:

Pool Type	ΔkWh			
	TOS/NC		Retrofit	
	ENERGY STAR	CEE T1	ENERGY STAR	CEE T1
In ground	307.7	N/A	1512.1	N/A

1359 Consistent with assumption in the 2020 ENERGY STAR calculator.
1360 Based on typical pool sizes from "Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains, The California Urban Water Conservation Council", 2010.
1361 Consistent with assumption in the 2020 ENERGY STAR calculator.
1362 Based on applying the federal standard specifications to the average Curve-C rated hydraulic horsepower (hhp) from the ENERGY STAR Qualified Products List, accessed 3/31/2021.
1363 Based on applying the ENERGY STAR and CEE Tier 1 specifications to the average Curve-C rated hydraulic horsepower (hhp) from the ENERGY STAR Qualified Products List, accessed 3/31/2021.
1364 Consistent with assumption in the 2020 ENERGY STAR calculator, assuming 1.5 HP pump.
1365 Consistent with assumption in the 2020 ENERGY STAR calculator.

Pool Type	ΔkWh			
	TOS/NC		Retrofit	
	ENERGY STAR	CEE T1	ENERGY STAR	CEE T1
Above ground	189.5	499.5	283.7	593.6

SUMMER COINCIDENT PEAK DEMAND SAVINGS

For TOS and NC:

$\Delta kW = ((kWh/day_{base})/(Hrs/day_{base}) – (kWh/day_{ESTAR})/(Hr/day_{ESTAR})) * CF$

For Early Replacement:

$\Delta kW = ((kWh/day_{Exist})/(Hrs/day_{Exist}) – (kWh/day_{ESTAR})/(Hr/day_{ESTAR})) * CF$

Where:

kWh/day = daily energy consumption of pool pump, as defined above.

= Actual, defaults provided below:

Pool Type	ΔkWh/day			
	Base	ENERGY STAR	CEE T1	Exist
In ground	9.5	7.0	N/A	19.4
Above ground	5.9	4.3	1.8	6.6

Hrs/day_{base} = daily run hours of pool pump

= (Gallons * Turnover) / GPM

		Weighted Average GPM[1366]	Hours/Day
In ground	Base	43.6	16.8
	Efficient	32.2	22.8
	Exist	78	9.4
Above ground	Base	44.7	5.6
	Efficient	27.3	9.2
	Exist	78.1	3.2

CF = Summer Peak Coincidence Factor for measure

= 0.831[1367]

Based on defaults provided above:

[1366] The 2013 ENERGY STAR calculator provided high and low flow and hour assumptions for multi and variable speed pumps. This is used to estimate a weighted average GPM assumption, see 'IL TRM_Pool Pump Calculator.xls'.

[1367] Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.

Pool Type	ΔkW			
	TOS/NC		Retrofit	
	ENERGY STAR	CEE T1	ENERGY STAR	CEE T1
In ground	0.2152	N/A	1.4641	N/A
Above ground	0.4793	0.7094	1.3285	1.5586

Mid-Life Baseline Adjustment

For early replacement measures, to account for the fact that the existing pump would have needed to be replaced within the lifetime of the measure, a mid-life adjustment should be applied. This is calculated as the savings from the federal standard to the ESTAR pump divided by the savings from the existing pump. This should be applied after 4 years.

Based on defaults provided above:

Pool Type	Adjustment Factor applied to Annual kWh Savings	
	ENERGY STAR	CEE T1
In ground	20%	N/A
Above ground	67%	84%

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-MSC-RPLP-V03-220101

Review Deadline: 1/1/2025

5.7.2 Low Flow Toilets

Description

The first federal standards dealing with water consumption for toilets was the Energy Policy Act of 1992. It specified a gallon per flush (gpf) standard for both fixtures. These standards are used to define the baseline equipment for this measure. The Subsequent U.S. EPA WaterSense program in 2009 set even tighter standards for plumbing fixtures, including toilets. These standards are used to define the efficient equipment for this measure.

Definition of Efficient Equipment

The high efficiency equipment is a U.S. EPA WaterSense certified residential toilet fixture.

Definition of Baseline Equipment

The baseline equipment is a toilet that has a maximum gallons per flush outlined by the Energy Policy Act of 1992.

Deemed Lifetime of Efficient Equipment

The estimated useful life for this measure is assumed to be 25 years.[1368]

Deemed Measure Cost

The incremental costs for both are $0.[1369]

Loadshape

Loadshape R03 - Residential Electric DHW

Coincidence Factor

N/A

Algorithm

Calculation of Energy Savings

Electric Energy Savings

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.

$$\Delta kWh = \Delta Water / 1{,}000{,}000 * Ewater\ total$$

Ewater = IL Total Water Energy Factor (kWh/Million Gallons)

= 5,010[1370]

1368 http://www.metrohome.us/information_kit_files/life.pdf and ATD Home Inspection: http://www.atdhomeinspection.com/advice/average-product-life/ is 50 years. 25 years is used to be conservative.

1369 Measure cost assumption from City of Fort Collins, "Green Building Practice Summary," March 21, 2011, page 2. The document states "Information from the EPA WaterSense web site: WaterSense® labeled toilets are not more expensive than regular toilets. MaP testing results have shown no correlation between price and performance. Prices for toilets can range from less than $100 to more than $1,000. Much of the variability in price is due to style, not functional design."

1370 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'.

Toilet Calculation

For example, a low flow toilet is installed in a single family home with unknown occupancy.

ΔkWh = 1495 / 1,000,000 * 5,010

= 7.5 kWh/year

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water = (GPF_{Base} - GPF_{Eff}) * NFPD * Household * ADPY$$

Where:

GPF_{Base} = Baseline equipment gallons per flush

= 1.6 for toilets[1371]

GPF_{Eff} = Efficient equipment gallons per flush

= 1.28 for toilets[1372]

NFPD = Number of flushes per day per occupant

= 5 [1373]

Household = Number of people in the houshold.

= Actual. If unknown assume average number of people per household:

Household Unit Type[1374]	Household
Single-Family - Deemed	2.56[1375]
Multi-Family - Deemed	2.1[1376]
Household type unknown	2.42[1377]
Custom	Actual Occupancy or Number of Bedrooms[1378]

Use Multifamily if: Building meets utility's definition for multifamily

ADPY = Annual days per year

[1371] U. S. EPA WaterSense. "Water Efficiency Management Guide – Bathroom Suite" (EPA 832-F-17-016d), Nov 2017.

[1372] U. S. EPA WaterSense. "Water Efficiency Management Guide – Bathroom Suite" (EPA 832-F-17-016d), Nov 2017.

[1373] U.S. EPA WaterSense, "Water Specification for Flushing Urinals Supporting Statement." Appendix B: References for Calculation Assumptions.

[1374] If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

[1375] 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

[1376] ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

[1377] 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.

[1378] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

= 365 for residential

Toilet Calculation

For example, a low flow toilet is installed in a single family home with unknown occupancy.

ΔWater = [(1.6 – 1.28) x 5 x 2.56 x 365

= 1495 gal/year

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-MSC-LFTU-V02-220101

REVIEW DEADLINE: 1/1/2023

5.7.3 Level 2 Electric Vehicle Charger

DESCRIPTION

The measure is for the purchase of a Level 2 electric vehicle charger consistent with the ENERGY STAR specification for Electric Vehicle Supply Equipment (EVSE) installed for residential household use. Networked chargers enable access to online energy management tools through an EVSE network. Non-networked chargers are standalone units that are not connected to other units through an EVSE network.

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

An ENERGY STAR qualified networked or non-networked level 2 electric vehicle charger.

DEFINITION OF BASELINE EQUIPMENT

A non-ENERGY STAR networked or non-networked level 2 electric vehicle charger.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for the EV charger is assumed to be 10 years.[1379]

DEEMED MEASURE COST

The incremental cost for the EV charger is assumed to be $57.[1380]

LOADSHAPE

Loadshape R19 - Residential Electric Vehicle Charger

COINCIDENCE FACTOR

Coincidence factor is embedded in deemed demand reduction savings estimate, so the coincidence factor is assumed to be 1.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (((Hours\_PS + Hours\_US) * SP\_base) - (Hours\_PS * SP\_EEp + Hours\_US * SP\_EEu))/ 1000)$$

Where:

Hours_C = Annual Active Charging Hours

[1379] Based on Northwest Power and Conservation Council, Regional Technical Forum workbook for Level 2 Electric Vehicle Charger version 1.1. approved May 2019. https://rtf.nwcouncil.org/measure/level-2-electric-vehicle-charger

[1380] Weighted average incremental cost based on limited data provided in Northwest Power and Conservation Council, Regional Technical Forum workbook for Level 2 Electric Vehicle Charger version 1.1. approved May 2019. https://rtf.nwcouncil.org/measure/level-2-electric-vehicle-charger. Recommend this assumption be reviewed in future versions.

= EV_kWh / Steady State Charger Output Capacity (kW)

= EV_kWh / 8.2[1381]

= 336 hours

EV_kWh = Annual Driving Energy Consumed at Home (kWh)

= VMT * EV_ee / 100 * %Home_Charging

VMT = Annual vehicle miles traveled of the vehicle measure.

= 10,690 [1382]

EV_ee = Actual nameplate operation efficiency for electric vehicle expressed in kWh per 100 miles.

= 30 kWh per 100 miles[1383]

%Home_Charging = Percent of charging that is done at home

= 86%[1384]

= 2,758 kWh

Hours_P = Total Annual Hours Plugged In

= Annual # of Charging Sessions * Average EV Plug in Time per Charging Session (Hrs)

= (EV_kWh / 7.4 [1385]) * 14.7 [1386]

= 5,479 hours

Hours_PS = Annual Standby Hours Plugged In

= Hours_P - Hours_C

= 5,143 hours

Hours_US = Annual Standby Hours Unplugged

= 8760 - Hours_P

= 3,281 hours

SP_base = Baseline Average Standby Power (W)

= 3.7 for non-networked, 9.9 for networked[1387]

SP_EEp = Efficient Average Standby Power (W) with vehicle plugged in

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1381 Analysis of WA and OR Cumulative EV Registrations through 2018 paired with Vehicle Maximum Power Acceptance (kW) data from Chargehub https://chargehub.com/en/find-the-right-charging-station-power.html

1382 Average annual vehicle miles traveled estimated based on Stateside average of data from the 2017 National Household Transportation survey, accessed 07/2020.

1383 Average electric vehicle efficiency based on light-duty vehicle miles per gallon from Annual Energy Outlook 2019. U.S. Energy Information Administration.

1384 Assumption consistent with RTF characterization based on 2014 Idaho National Laboratory study.

1385 Avista Docket No. UE-160082 – Avista Utilities Semi-Annual Report on Electric Vehicle Supply Equipment Pilot Program (November 2018) Table 13 Avg. kWh Consumed per Session

1386 Based on data provided by Avista. Total hours EV is plugged into charging station including both charge and standby time.

1387 INL charger testing https://avt.inl.gov/evse-type/ac-level-2 and ENERGY STAR Market and Industry Scoping Report Electric Vehicle Supply Equipment (EVSE) September 2013 (source data is from INL).

= 4.3 for non-networked, 6.4 for networked[1388]

SP_EEu = Efficient Average Standby Power (W) in no vehicle mode

= 2.1 for non-networked, 3.2 for networked[1389]

ΔkWh per non-networked charger = (((5,143 + 3,281) * 3.7) - (5,143 * 4.3 + 3,281 * 2.1))/ 1000)

= 2.2 kWh

ΔkWh per networked charger = (((5,143 + 3,281) * 9.9) - (5,143 * 6.4 + 3,281 * 3.2))/ 1000)

= 40.0 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = - kW_vehicle * CF

Where:

kW_vehicle = Summer peak electric demand of the electric vehicle.

= 0.28 kW[1390]

CF = Summer peak coincidence factor

= 1[1391]

NATURAL GAS SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-MSC-L2CH-V01-210101

REVIEW DEADLINE: 1/1/2023

1388 2019 ENERGY STAR QPL of Residential EVSE. No Residential units, used commercial as a proxy. Averaged Partial On Mode Input Power (W) and Idle Mode Input Power (W)

1389 2019 ENERGY STAR QPL of Residential EVSE. No Residential units, used commercial as a proxy. Averaged Partial On Mode Input Power (W) and Idle Mode Input Power (W).

1390 Summer peak demand impacts are a deemed value based on EV Charging Station Pilot Evaluation Report. Xcel CO. May 2015. Page 5.

1391 kW_Vehicle accounts for the estimated average kW draw during the system peak.