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2023 Illinois Statewide Technical Reference Manual for Energy Efficiency

Version 11.0

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

FOSSIL FUEL 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, ENERGY STAR Most Efficient/CEE Tier 2 or CEE Advanced Tier 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, ENERGY STAR Most Efficient/CEE Tier 2 or CEE Advanced Tier 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
ENERGY STAR Most Efficient/CEE Tier 2	≥2.92 IMEF, ≤3.2 IWF	
CEE Advanced Tier	≥3.1 IMEF, ≤3.0 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 $87, for a ENERGY STAR Most Efficient/CEE Tier 2 unit it is $85 and for a CEE Advanced Tier it is $99.[14]

DEEMED O&M COST ADJUSTMENTS

N/A

[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 analysis of cost data provided in the 2017 Department of Energy Technical Support Document (see IL_TRM_CW Analysis_042022.xlsx). This analysis looked at incremental cost and market data from the CEC Appliance Database and attempts to find the costs associated only with the efficiency improvements. Note that the incremental cost assumes a mix of top and front loading machines available in each efficiency tier. Since CEE T2 and Advanced Tier units are all front loading, and the incremental cost is lower for these machines, the T2 incremental cost is lower than ENERGY STAR which is based on a mix of front and top loading machines..

LOADSHAPE

Loadshape R01 - Residential Clothes Washer

COINCIDENCE FACTOR

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

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 3.55 cubic feet[18]

IMEFbase = Integrated Modified Energy Factor of baseline unit

= 1.71[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]

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

[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 04/21/2022. 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 04/21/2022).

[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.

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

Efficiency Level	IMEF	IMEF Savings (kWh)
Federal Standard	1.75	0.0
ENERGY STAR	2.21	139.6
ENERGY STAR Most Efficient/CEE Tier 2	2.92	254.8
CEE Advanced Tier	3.10	275.6

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	6.7%	15.8%	77.5%
ENERGY STAR	6.6%	13.0%	80.4%
ENERGY STAR Most Efficient/CEE Tier 2	8.2%	8.8%	82.9%
CEE Advanced Tier	8.9%	7.0%	84.1%

%Electric_DHW = Percentage of DHW savings assumed to be electric

= 100 % for Electric

= 0 % for Fossil Fuel

= If unknown[23], use the following table:

[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.

[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 the 2017 DOE Life-Cycle Cost and Payback Period Excel-based analytical tool. See "IL TRM_CW Analysis_042022.xlsx" for the calculation.

[23] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

	Location				
Utility	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[24]	24%	25%	40%	43%	28%
ComEd[25]	8%		11%		9%
People's Gas[26]	23%	26%	49%	50%	63%
Northshore Gas[27]	20%				
Nicor Gas[28]	20%				
All DUs					28%

%Electric_Dryer = Percentage of dryer savings assumed to be electric

Dryer fuel	%Electric_Dryer
Electric	100%
Natural Gas	0%
Unknown	69%[29]

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

	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	139.6	104.3	45.3	10.1	110.3	75.1	114.2	19.9	85.0
ENERGY STAR Most Efficient/CEE Tier 2	254.8	189.4	77.1	11.7	199.7	134.4	207.7	30.0	152.7
CEE Advanced Tier	275.6	202.3	84.5	11.1	210.8	154.5	235.1	26.0	170.3

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.

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

[24] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.
[25] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.
[26] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.
[27] Ibid.
[28] Comparable service area & customers to NSG, therefore using their survey data.
[29] Based on Applied Energy Group, 2016 'Ameren Illinois Demand Side Management Market Potential Study: Volume 4 – APPENDICES'.

Where

ΔWater (gallons) = Water saved, in gallons – as calculated below.

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

=5,010[30]

Using defaults provided:

ENERGY STAR ΔkWh_{water} = 1,595/1,000,000 * 5,010

= 8.0 kWh

ENERGY STAR Most Efficient/CEE Tier 2 ΔkWh_{water} = 2,500/1,000,000 * 5,010

= 12.5 kWh

CEE Advanced Tier ΔkWh_{water} = 2,709/1,000,000 * 5,010

= 13.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

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

Hours = Assumed Run hours of Clothes Washer

= 295 hours[31]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[32]

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

	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	0.0180	0.0134	0.0058	0.0013	0.0142	0.0097	0.0147	0.0026	0.0109
ENERGY STAR Most Efficient/CEE Tier 3	0.0328	0.0244	0.0099	0.0015	0.0257	0.0173	0.0268	0.0039	0.0197
CEE Advanced Tier	0.0355	0.0261	0.0109	0.0014	0.0272	0.0199	0.0303	0.0034	0.0219

[30] 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'.

[31] 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)

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

FOSSIL FUEL 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 * %Fossil_DHW * R_eff) + (%Dryerbase * %Gas _Dryer))) – (Capacity * 1/IMEFeff * Ncycles * ((%DHWeff * %Fossil_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[33]

%Fossil_DHW = Percentage of DHW savings assumed to be Fossil Fuel

= 100 % for Fossil fuel

= 0 % for Electric

= If unknown[34], use the following table:

	Location				
Utility	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[35]	76%	75%	60%	57%	72%
ComEd[36]	92%		89%		91%
People's Gas[37]	77%	74%	51%	50%	37%
Northshore Gas[38]	80%				
Nicor Gas[39]	80%				
All DUs					**72%**

%Fossil_Dryer = Percentage of dryer savings assumed to be fossil fuel

Dryer fuel	%Gas_Dryer
Electric	0%

[33] 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.

[34] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

[35] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

[36] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

[37] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

[38] Ibid.

[39] Comparable service area & customers to NSG, therefore using their survey data.

Dryer fuel	%Gas_Dryer
Fossil Fuel	100%
Unknown	31%[40]

Other factors as defined above.

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

	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	1.5	3.2	4.7	1.0	2.5	1.1	4.3	2.1
ENERGY STAR Most Efficient/CEE Tier 2	0.0	2.8	6.1	8.9	4.7	4.7	2.0	8.1	3.9
CEE Advanced Tier	0.0	3.2	6.5	9.7	4.6	4.6	1.7	8.9	4.0

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

= 5.59[41]

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[42]	ΔWater (gallons per year)
Federal Standard	5.59	0.0
ENERGY STAR	4.07	1,595
ENERGY STAR Most Efficient/CEE Tier 2	3.20	2,500
CEE Advanced Tier	3.0	2,709

Deemed O&M Cost Adjustment Calculation

N/A

[40] Based on Applied Energy Group, 2016 'Ameren Illinois Demand Side Management Market Potential Study: Volume 4 – APPENDICES'.

[41] 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 04/21/2022).

[42] IWF values are the weighted average based upon the relative top v front loading percentage of available ENERGY STAR, CEE Tier 2 and CEE Advanced Tier products in the CEC database (products accessed on 04/21/2022). See "IL TRM_CW Analysis_042022.xlsx" for the calculation.

MEASURE CODE: RS-APL-ESCL-V10-230101

REVIEW DEADLINE: 1/1/2025

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.[43] 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:

[43] EPA Research, 2012; ENERGY STAR Appliance Calculator, Dehumidifier Section

Equipment Specification	ENERGY STAR	ENERGY STAR Most Efficient
Portable Dehumidifier	$10[44]	$75[45]

LOADSHAPE

Loadshape R12 - Residential - Dehumidifier

COINCIDENCE FACTOR

The coincidence factor is assumed to be 50%.[46]

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[47]

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[48] (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[49]	38.9	1.54	1.75	1.86	1095	962	907

[44] 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.

[48] 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[50]

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

FOSSIL FUEL SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[46] 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%

[47] 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.

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

[49] 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”

[50] 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[51]	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.[52]

Deemed Measure Cost

The incremental cost for standard and compact dishwashers is provided in the table below:[53]

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

[51] 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.

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

[53] 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%.[54]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh^{55} = ((kWh_{Base} - kWh_{ESTAR}) * (\%kWh\_op + (\%kWh\_heat * \%Electric\_DHW)))$$

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%[56]

= 44%

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

= 56%[57]

%Electric_DHW = Percentage of DHW savings assumed to be electric

= 100 % for Electric

= 0 % for Fossil Fuel

[54] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.
[55] 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.
[56] ENERGY STAR Qualified Appliance Savings Calculator, last updated October 2016.
[57] Ibid.

= If unknown[58], use the following table:

	Location				
Utility	**Single Family**	**Single Family Low Income**	**Multi Family**	**Multi Family Low Income**	**Unknown**
Ameren[59]	24%	25%	40%	43%	28%
ComEd[60]	8%		11%		9%
People's Gas[61]	23%	26%	49%	50%	63%
Northshore Gas[62]	20%				
Nicor Gas[63]	20%				
All DUs					28%

Dishwasher Type	ΔkWh		
	With Electric DHW	With Gas DHW	With Unknown location and building type DHW
ENERGY STAR Standard	37.0	16.3	22.1
ENERGY STAR Standard with Connected Functionality	24.0	10.6	14.3
ENERGY STAR Compact	19.0	8.4	11.3

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[64]

Using defaults provided:

[58] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.
[59] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.
[60] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.
[61] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.
[62] Ibid.
[63] Comparable service area & customers to NSG, therefore using their survey data.
[64] 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'.

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[65]

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

Where:

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

Hours = Annual operating hours[66]

= 353 hours

CF = Summer Peak Coincidence Factor

= 2.6% [67]

Dishwasher Type	ΔkW		
	With Electric DHW	With Gas DHW	With Unknown location and building type DHW
ENERGY STAR Standard	0.0027	0.0012	0.0016
ENERGY STAR Standard with Connected Functionality	0.0018	0.0008	0.0011
ENERGY STAR Compact	0.0014	0.0006	0.0008

FOSSIL FUEL SAVINGS

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

Where

%kWh_heat = % of dishwasher energy used for water heating

= 56%

%Fossil_DHW = Percentage of DHW savings assumed to be fossil fuel

= 100 % for Fossil Fuel

= 0 % for Electric

= If unknown[68], use the following table:

[65] 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.

[66] 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.

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

[68] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[69]	76%	75%	60%	57%	72%
ComEd[70]	92%		89%		91%
People's Gas[71]	77%	74%	51%	50%	37%
Northshore Gas[72]	80%				
Nicor Gas[73]	80%				
All DUs					**72%**

R_eff = Recovery efficiency factor

= 1.26[74]

0.03412 = factor to convert from kWh to Therm

Dishwasher Type	ΔTherms		
	With Electric DHW	With Gas DHW	With Unknown location and building type DHW
ENERGY STAR Standard	0.00	0.89	0.64
ENERGY STAR Standard with Connected Functionality	0.00	0.58	0.42
ENERGY STAR Compact	0.00	0.46	0.33

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Where

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

[69] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

[70] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

[71] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

[72] Ibid.

[73] Comparable service area & customers to NSG, therefore using their survey data.

[74] 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) [75]
Standard	840
Compact	588

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

Dishwasher Type	$Water_{EFF}$ (gallons) [76]
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-V08-230101

Review Deadline: 1/1/2024[77]

[75] 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.

[76] Ibid

[77] ESTAR V7.0 currently in draft (2nd round), likely effective mid-2023. Holding revisions until Final draft of specs have been released.

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[78]	ENERGY STAR Maximum Energy Usage in kWh/year[79]
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.

[78] See Department of Energy Federal Standards, (10 CFR Part 430.32(a)), effective September 15th, 2014.
[79] See Version 5.1 ENERGY STAR specification.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 21 years for standard size and 10 years for compact freezers.[80]

Deemed Measure Cost

The incremental cost for this measure is $5.[81]

Loadshape

Loadshape R04 - Residential Freezer

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 95%.[82]

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	Adjusted Volume Used[83]	Assumptions after September 2014		
		kWh_{BASE}	kWh_{ESTAR}	ΔkWh
Upright Freezers with Manual Defrost	15.0	277.3	249.5	27.8
Upright Freezers with Automatic Defrost	26.2	453.9	408.6	45.3
Chest Freezers and all other Freezers except Compact Freezers	22.5	271.9	244.7	27.2

[80] Based on 2021 DOE Rulemaking Technical Support Document, “Refrigerator, Refrigerator-Freezer, and Freezer Life-Cycle Cost (LCC) Analysis Spreadsheet” posted November 9, 2021.

[81] Costs are estimated using the data provided in the Department of Energy, “Refrigerator, Refrigerator-Freezer, and Freezer Life-Cycle Cost (LCC) Analysis Spreadsheet” posted November 9, 2021 as part of the ‘Energy Conservation Standards for Consumer Refrigerators, Refrigerator-Freezers, and Freezers’ rulemaking docket. Install cost data was trended to provide estimates at the efficiency levels specified in this measure, and then weighted based on available product on the ENERGY STAR Freezer QPI, accessed 4/29/2022. See “DOE LCC Spreadsheet_Freezer.xls” for more information.

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

[83] Volume is based on average adjusted volume of units on the ENERGY STAR QPI, accessed 4/29/2022. See “DOE LCC Spreadsheet_Freezer.xls” for more information.

Product Category	Adjusted Volume Used[83]	Assumptions after September 2014		
		kWh_{BASE}	kWh_{ESTAR}	ΔkWh
Compact Upright Freezers with Manual Defrost	5.5	273.3	246.0	27.3
Compact Upright Freezers with Automatic Defrost	7.5	428.6	385.7	42.9
Compact Chest Freezers	9.5	224.8	202.4	22.5

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/ Hours * CF

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Full Load hours per year

= 5890[84]

CF = Summer Peak Coincident Factor

= 0.95 [85]

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

ΔkW = 26.9/5890 * 0.95

= 0.0043 kW

If volume is unknown, use the following default values:

Product Category	Assumptions after September 2014
	kW Savings
Upright Freezers with Manual Defrost	0.0045
Upright Freezers with Automatic Defrost	0.0073
Chest Freezers and all other Freezers except Compact Freezers	0.0044
Compact Upright Freezers with Manual Defrost	0.0044
Compact Upright Freezers with Automatic Defrost	0.0069
Compact Chest Freezers	0.0036

Fossil Fuel Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

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

MEASURE CODE: RS-APL-ESFR-V04-230101

REVIEW DEADLINE: 1/1/2024

5.1.6 ENERGY STAR, CEE Tier 2 or CEE Tier 3 Refrigerator

DESCRIPTION

This measure relates to:

a) Time of Sale: the purchase and installation of a new refrigerator meeting either ENERGY STAR, CEE TIER 2 or TIER 3 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, CEE Tier 2 or Tier 3 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[86]	ENERGY STAR Maximum Energy Usage in kWh/year[87]
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, CEE Tier

86 See Department of Energy Federal Standards (10 CFR Part 430.32(a)), effective September 15th, 2014.

87 See Version 5.0 ENERGY STAR specification.

2 or CEE Tier 3 (defined as requiring >= 10%, >= 15% or >=20% 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. This Federal Standard is effective for units manufactured after September 1, 2014. Note in December 2021, the DOE presented preliminary analysis for the purposes of evaluating energy conservation standards. The review deadline will be set for one further year to review progress in standard updates.

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 15 years.[88]

Remaining life of existing equipment is assumed to be 5 years.[89]

DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $28 for an ENERGY STAR unit, $112 for a CEE Tier 2 unit and $134 for a CEE Tier 3 unit.[90]

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 $872 for ENERGY STAR unit, $956 for CEE Tier 2 unit and $978 for CEE Tier 3 units.

The avoided replacement cost (after 5 years) of a baseline replacement refrigerator is $844. 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.

---

[88] Based on 2021 DOE Rulemaking Technical Support Document, “Refrigerator, Refrigerator-Freezer, and Freezer Life-Cycle Cost (LCC) Analysis Spreadsheet” posted November 9, 2021.

[89] Standard assumption of one third of effective useful life.

[90] Costs are estimated using the data provided in the Department of Energy, “Refrigerator, Refrigerator-Freezer, and Freezer Life-Cycle Cost (LCC) Analysis Spreadsheet” posted November 9, 2021 as part of the ‘Energy Conservation Standards for Consumer Refrigerators, Refrigerator-Freezers, and Freezers’ rulemaking docket. Install cost data was trended to provide estimates at the efficiency levels specified in this measure, and then weighted based on available product on the ENERGY STAR Refrigerator QPI, accessed 4/29/2022. See “DOE LCC Spreadsheet.xls” for more information.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS:

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

Early Replacement:

ΔkWh for remaining life of existing unit (1st 5 years) $= UEC_{EXIST} - UEC_{EE}$

ΔkWh for remaining measure life (next 10 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 and for CEE Tier 3 20% lower than baseline.

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 22.9:[91]

Assumptions after standard changes on September 1st, 2014:

Product Category	Existing Unit UEC_{EXIST} [92]	New Baseline UEC_{BASE}	New Efficient UEC_{EE}			Early Replacement (1st 5 years) ΔkWh			Time of Sale and Early Replacement (last 10 years) ΔkWh		
			ENERGY STAR	CEE T2	CEE T3	ENERGY STAR	CEE T2	CEE T3	ENERGY STAR	CEE T2	CEE T3
1. Refrigerators and Refrigerator-freezers with manual defrost	998.2	349.2	314.2	296.8	279.4	684.0	701.4	718.9	35.0	52.4	69.8
2. Refrigerator-Freezer--partial automatic defrost	998.2	408.1	367.3	346.9	326.5	631.0	651.4	671.8	40.8	61.2	81.6
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	794.8	418.6	376.7	355.8	334.9	418.2	439.0	459.9	42.0	62.8	83.7

[91] Volume is based on the average adjusted volume of applicable units on the ENERGY STAR QPI, accessed 4/29/2022.

[92] 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 = 18.9 ft3 (average of applicably units on ENERGY STAR QPI, accessed 4/29/2022), 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} [92]	New Baseline UEC_{BASE}	New Efficient UEC_{EE}			Early Replacement (1st 5 years) ΔkWh			Time of Sale and Early Replacement (last 10 years) ΔkWh		
			ENERGY STAR	CEE T2	CEE T3	ENERGY STAR	CEE T2	CEE T3	ENERGY STAR	CEE T2	CEE T3
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	1201.6	492.8	443.5	418.9	394.2	758.1	782.7	807.4	49.3	73.9	98.6
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	794.8	519.8	467.9	441.8	415.8	326.9	353.0	379.0	51.9	78.0	104.0
5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	794.8	687.4	627.2	584.3	549.9	167.7	210.6	244.9	60.2	103.1	137.5
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	794.8	577.9	528.5	491.2	462.3	266.3	303.6	332.5	49.3	86.7	115.6
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	1201.6	628.5	574.1	534.2	502.8	627.5	667.4	698.8	54.4	94.3	125.7

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh/8766) * TAF * LSAF

Where:

TAF = Temperature Adjustment Factor

= 1.25[93]

LSAF = Load Shape Adjustment Factor

[93] 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).

= 1.057 [94]

If volume is unknown, use the following defaults:

Product Category	ΔkW					
	Early Replacement (1st 5 years)			Time of Sale and Early Replacement (last 10 years)		
	ENERGY STAR	CEE T2	CEE T3	ENERGY STAR	CEE T2	CEE T3
1. Refrigerators and Refrigerator-freezers with manual defrost	0.103	0.106	0.108	0.005	0.008	0.011
2. Refrigerator-Freezer--partial automatic defrost	0.095	0.098	0.101	0.006	0.009	0.012
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	0.063	0.066	0.069	0.006	0.009	0.013
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	0.114	0.118	0.122	0.007	0.011	0.015
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	0.049	0.053	0.057	0.008	0.012	0.016
5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	0.025	0.032	0.037	0.009	0.016	0.021
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	0.040	0.046	0.050	0.007	0.013	0.017
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	0.095	0.101	0.105	0.008	0.014	0.019

FOSSIL FUEL SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESRE-V09-230101

REVIEW DEADLINE: 1/1/2024

[94] 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)

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 26th 2015[95]) or CEE Tier 2 minimum qualifying efficiency specifications, in place of a baseline unit. The baseline is based on the Federal Standard effective June 1st, 2014.

Product Type and Class (Btu/hr)		Federal Standard with louvered sides (CEER) [96]	Federal Standard without louvered sides (CEER)	ENERGY STAR v4.0 / CEE Tier 1 with louvered sides (CEER) [97]	ENERGY STAR v4.0 / CEE Tier 1without louvered sides (CEER)	CEE Tier 2 (CEER)[98]
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.

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[95] ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
[96] See DOE's Appliance and Equipment Standards for Room AC;
[97] ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
[98] 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[99]) 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)[100] 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.[101]

Remaining life of existing equipment is assumed to be 4 years.[102]

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.[103]

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.[104]

The avoided replacement cost (after 4 years) of a baseline replacement unit is $432.[105] 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.[106]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

[99] ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
[100] See DOE's Appliance and Equipment Standards for Room AC.
[101] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[102] Standard assumption of one third of effective useful life.
[103] CEE Tier 1 cost based on field study conducted by Efficiency Vermont and Tier 2 based on professional judgement.
[104] 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.
[105] Estimate based upon Time of Sale incremental costs and applying inflation rate of 1.91%.
[106] 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 (1^{st} 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:[107]

Climate Zone (City based upon)	FLH_{RoomAC}
1 (Rockford)	220
2 (Chicago)	210
3 (Springfield)	319
4 (Belleville)	428
5 (Marion)	374
Weighted Average[108]	
ComEd	210
Ameren	338
Statewide	245

Btu/H = Size of rebated unit

= Actual. If unknown assume 8500 Btu/hr[109]

EERexist =Efficiency of existing unit

= Actual. If unknown assume 7.7 [110]

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption)[111]

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

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107 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.

108 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

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

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

111 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 (1^{st} 4 years) = (319 * 9000 * (1/(7.7/1.01) - 1/12.0))/1000

= 137.3 kWh

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

= 24.1 kWh

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[112]

1.01 = Factor to convert CEER to EER (CEER includes standby and off power consumption)[113]

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 (1^{st} 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

FOSSIL FUEL SAVINGS

N/A

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

113 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-V09-230101

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.[114]

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.[115]

LOADSHAPE

Loadshape R05 - Residential Refrigerator

COINCIDENCE FACTOR

The coincidence factor is assumed 1.081 for Refrigerators and 1.028 for Freezers[116].

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[114] 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.

[115] 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.

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

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS[117]

Refrigerators:

Energy savings for refrigerators are based upon a linear regression model using the following coefficients:[118]

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:[119]

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

[117] 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.

[118] 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".

[119] 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:[120]

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.[121] For illustration purposes, this example uses 0.93.[122]

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:[123]

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

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

[121] 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.

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

[123] 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.[124] For illustration purposes, the example uses 0.85.[125]

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[126]

[124] 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.

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

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

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

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

FOSSIL FUEL 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.[127]

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%.[128]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

[128] 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:[129]

Climate Zone (City based upon)	FLH_{RoomAC}
1 (Rockford)	220
2 (Chicago)	210
3 (Springfield)	319
4 (Belleville)	428
5 (Marion)	374
Weighted Average[130]	
ComEd	210
Ameren	338
Statewide	245

Btu/H = Size of retired unit

= Actual. If unknown assume 8500 Btu/hr [131]

EERexist = Efficiency of existing unit

= 9.8[132]

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

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

$= 276$ kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[133]

[129] 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.

[130] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

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

[132] 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.

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

For example, an 8500 Btu/h unit:

$$\Delta kW = (8500 * (1/9.8)) / 1000) * 0.3$$
$$= 0.26 \text{ kW}$$

FOSSIL FUEL SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RARC-V03-230101

REVIEW DEADLINE: 1/1/2025

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[134]. 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. Units utilizing the Heat Pump designation must meet the same ENERGY STAR criteria and be classified as Heat Pump or Hybrid Heat Pump units.

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.[135]

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.[136]

LOADSHAPE

Loadshape R17 - Residential Electric Dryer

COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%.[137]

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

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Non Fuel Switch Measures

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

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

Fuel Switch/Electrification Measures

Fuel switch / electrification measures must produce positive total energy savings (i.e., reduction in Btus at the premises) in order to qualify. This is determined as follows:

SiteEnergySavings (MMBTUs) = [FuelSwitchSavings] + [NonFuelSwitchSavings]

FuelSwitchSavings = [(Load/$CEFbase_{Gas}$ * Ncycles * MMBtu_convert * $\%Gas_{Gas}$] - [Load/$CEFeff_{Elec}$ * Ncycles * $\%Gas_{Gas}$ * 3412/1,000,000]

NonFuelSwitchSavings = [(Load/$CEFbase_{Gas}$ * Ncycles * MMBtu_convert * $\%Electric_{Gas}$] - [Load/$CEFeff_{Elec}$ * Ncycles * $\%Electric_{Gas}$ * 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

Where:

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

Dryer Size	Load (lbs)[138]
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

[138] Based on ENERGY STAR test procedures.

analysis.[139] 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[140]
Electric Heat Pump, Standard (≥ 4.4 ft^3)	3.11
Electric Heat Pump, Compact (120V) (< 4.4 ft^3)	3.01

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR or ENERGY STAR Most Efficient requirements.[141] 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[142]	3.8
Electric Heat Pump, Standard (≥ 4.4 ft^3)	3.93	6.5[143]
Electric Heat Pump, Compact (< 4.4 ft^3)	3.36	6.2[144]

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year.[145]

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 16% for gas dryers[146]

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

%Gas = Percent of overall savings coming from gas

[139] ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis
[140] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[141] ENERGY STAR Clothes Dryers Key Product Criteria.
[142] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[143] Average CEF of available standard ENERGY STAR Clothes Dryers with Heat Pump technology. EPA ENERGY STAR. May 2022. https://www.energystar.gov/productfinder/product/certified-clothes-dryers/.
[144] Average CEF of available compact ENERGY STAR Clothes Dryers with Heat Pump technology. EPA ENERGY STAR. May 2022. https://www.energystar.gov/productfinder/product/certified-clothes-dryers/.
[145] Appendix D to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Dryers.
[146] %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.

= 0% for electric units and 84% for gas units[147]

MMBtu_convert = Conversion factor from kWh to Therm

= 0.003412

Electric 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

Gas 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

ΔkWh = ((8.45/2.84 – 8.45/3.48) * 283 * 0.16)

= 24.8 kWh

Fuel switch example, for a Time of Sale, an ENERGYSTAR Most Efficient Heat Pump clothes dryer in place of a baseline gas dryer:

SiteEnergySavings (MMBTUs) = [FuelSwitchSavings] + [NonFuelSwitchSavings]

FuelSwitchSavings = [(Load/$CEFbase_{Gas}$ * Ncycles * MMBtu_convert * $\%Gas_{Gas}$] - [Load/$CEFeff_{Elec}$ * Ncycles * $\%Gas_{Gas}$ * 3412/1,000,000]

= (8.45/2.84 * 283 * 0.003412 * 0.84) - (8.45/5.7 * 283 * 0.84 * 3412/1000000)

= 1.21 MMbtu

NonFuelSwitchSavings = [(Load/$CEFbase_{Gas}$ * Ncycles * MMBtu_convert * $\%Electric_{Gas}$] - [Load/$CEFeff_{Elec}$ * Ncycles * $\%Electric_{Gas}$ * 3412/1,000,000]

= (8.45/2.84 * 283 * 0.003412 * 0.16) - (8.45/5.7 * 283 * 0.16 * 3412/1000000)

= 0.23 MMBtu

SiteEnergySavings (MMBTUs) = 1.21 + 0.23

= 1.44 MMBtu

If supported by an electric utility: ΔkWh = ΔSiteEnergySavings * 1,000,000 / 3,412

= 1.44 * 1,000,000/3412

= 422.5 kWh

[147] %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.

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.[148]

CF = Summer Peak Coincidence Factor for measure

= 3.8%[149]

> **For example**, for a Time of Sale, a standard, vented, electric ENERGY STAR clothes dryer:
>
> ΔkW = 160/283 * 3.8%
>
> = 0.0215 kW

Fossil Fuel 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 fossil fuel to electric.

For the purposes of forecasting load reductions due to fuel switch 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 "Fossil Fuel Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Gas Dryer Consumption Replaced]

= [(Load/$CEFbase_{Gas}$ * Ncycles * Therm_convert * $\%Gas_{Gas}$]

ΔkWh = [Gas Dryer Electric Consumption Replaced] - [Electric Dryer Consumption Added]

= [Load/$CEFeff_{Gas}$ * Ncycles * $\%Electric_{Gas}$] – [Load/$CEFeff_{Elec}$ * Ncycles * $\%Electric_{Electric}$]

148 ENERGY STAR qualified dryers have a maximum test cycle time of 80 minutes. Assume one hour per dryer cycle.

149 Based on coincidence factor of 3.8% for clothes washers.

MEASURE CODE: RS-APL-ESDR-V05-230101

REVIEW DEADLINE: 1/1/2026

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.[150]

Deemed Measure Cost

The incremental cost for this measure is estimated at $17.[151]

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[152]

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

[150] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
[151] Ameren Missouri PY3 Evaluation Report.
[152] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.

kWh_{ee} = Daily energy use (kWh/day) for ENERGY STAR water cooler[153]

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[154]

Energy Savings:

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

DEMAND SAVINGS

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

Where:

Hours = Number of hours per year water cooler is in use
= 8766 hours[155]

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

FOSSIL FUEL SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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153 Average kWh/day for from the ENERGY STAR efficient product database.
154 Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
155 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.[156]

DEEMED MEASURE COST

The deemed measure cost is $300 for a new single-unit ozone laundry system.[157]

LOADSHAPE

Loadshape R01 – Residential Clothes Washer

COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%.[158]

[156] 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).
[157] 2018 GTI Residential Ozone Laundry Field Demonstration (May 2018).
[158] 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

= 100 % for Electric

= 0 % for Fossil Fuel

= If unknown[159], use the following table:

Utility	Location: Single Family	Location: Single Family Low Income	Location: Multi Family	Location: Multi Family Low Income	Location: Unknown
Ameren[160]	24%	25%	40%	43%	28%
ComEd[161]	8%		11%		9%
People's Gas[162]	23%	26%	49%	50%	63%
Northshore Gas[163]	20%				
Nicor Gas[164]	20%				
All DUs					**28%**

Capacity = Clothes washer capacity (cubic feet).

= Actual. If unknown, assume 5.0 cubic feet.[165]

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

= Actual. If unknown, use the following values

Efficiency Level	IWF (gallons/cycle/ft3)

[159] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

[160] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

[161] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

[162] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

[163] Ibid.

[164] Comparable service area & customers to NSG, therefore using their survey data.

[165] 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.

	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.[166]

Single-Family Home	Multifamily
0.1759	0.2960

T_{OUT} = Tank temperature

= 125°F

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

= 50.7°F [167]

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[168]	1,243[169]

RE_electric = Recovery efficiency of electric water heater

= 0.98[170] for Electric Resistance

= 3.51[171] for Electric HPWH

3412 = Btus to kWh conversion (Btu/kWh)

$\%HotWash_{base}$ = Average percentage of loads that use hot or warm water with baseline equipment. [172]

[166] 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.

[167] 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.

[168] 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.

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

[170] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

[171] Review of AHRI database shows that Electric Heat Pump Water Heaters support this recovery efficiency. For the raw data, and calculations, please see AHRI_ RES Water Heaters 2022.xlsx.

[172] 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.

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

= 264 hours[173]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[174]

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

Fossil Fuel 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 = Percentage of DHW savings assumed to be fossil fuel

= 100 % for Fossil Fuel

= 0 % for Electric

= If unknown[175], use the following table:

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

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

175 Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

Utility	Location: Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[176]	76%	75%	60%	57%	72%
ComEd[177]	92%		89%		91%
People's Gas[178]	77%	74%	51%	50%	37%
Northshore Gas[179]	80%				
Nicor Gas[180]	80%				
All DUs					**72%**

RE_gas = Recovery efficiency of gas water heater

Single-Family Homes	Multifamily
79%[181]	67%[182]

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)/(0.79 * 100,000)*(0.7743 – 0)

= 10.2 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

LAUNDRY DETERGENT SAVINGS

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

176 Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

177 Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

178 Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

179 Ibid.

180 Comparable service area & customers to NSG, therefore using their survey data.

181 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 79%.

182 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.

Detergent savings per year = Detergent_cost * Ncycles

Where:

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

= 0.16[183]

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-V05-230101

REVIEW DEADLINE: 1/1/2026

183 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)[184] 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)[185]
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.

184 ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements

185 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.[186]

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.[187] If a CEE Tier 2 unit is installed assume $508.[188]

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%[189]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 46.6%[190]

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

186 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
187 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.
188 Consistent with Non IQ version of the measure.
189 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
190 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

= dependent on location:

Climate Zone (City based upon)	FLHcool (single family)	FLHcool (multifamily)	FLH_cooling (weatherized multifamily)[191]
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[192]			
ComEd	567	504	323
Ameren	810	734	470
Statewide	632	565	362

Btu/H = Size of installed unit

= Actual. If unknown assume 8500 Btu/hr[193]

EERbase =Efficiency of existing / baseline unit

= Actual. If unknown assume 7.7 [194]

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption)[195]

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)

191 *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.

192 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

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

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

195 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'.

= 68%[196]

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

= 46.6%[197]

1.02 = Factor to convert CEER to EER (CEER includes standby and off power consumption)[198]

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

FOSSIL FUEL SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-IQRA-V03-230101

REVIEW DEADLINE: 1/1/2024

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

[197] 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.

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

5.1.14 Residential Induction Cooktop

DESCRIPTION

A fully electric range with an electric oven and an induction cooktop or a freestanding induction cooktops installed in place of an electric range with an electric resistance cooktop, natural gas range, or a freestanding electric resistance cooktop.

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 freestanding cooktop that heats cooking vessels using electrical induction or a range with an electric resistance oven and an electric induction cooktop for residential applications.

DEFINITION OF BASELINE EQUIPMENT

The baseline reflects the cooking efficiencies of electric resistance cooktops and gas cooktops. Cooking efficiency is defined as the ratio of energy absorbed by the object being heated (food, water, etc.) and the energy consumed by the appliance.

Cooktop Type	Cooking Efficiency[199]
Electric Resistance	77%
Natural Gas	32%

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the measure is 16 years.[200]

DEEMED MEASURE COST

The incremental cost for ovens with induction cooktops compared to a baseline oven with resistance or gas cooktop is assumed to be $949 and the incremental cost for induction cooktop only over resistance or gas cooktop is $687[201]. In addition, assume $100 additional labor from an electric baseline to install additional power/socket requirements, and an additional $200 labor from a gas baseline to also cap the gas line.[202]

LOADSHAPE

Loadshape R20 – Residential Induction Cooktop

COINCIDENCE FACTOR

The coincidence factor is assumed to be 29%.[203]

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[199] The cooking efficiencies of electric resistance, gas, and induction cooktops are tested and calculated in the *Residential Cooktop Performance and Energy Comparison Study* conducted by Frontier Energy.

[200] The EUL was developed for the U.S. Department of Energy (DOE) Energy Conservation Program, Energy Conservation Standards for Residential Conventional Cooking Products as part of the 2016 supplemental notice of proposed rulemaking (SNOPR).

[201] Southern California Edison (SCE). 2019. "SWAP015-01 Costs.xlsx". This reference only looked at electric ovens/cooktops, but VEIC compared baseline electric and gas units and found very little difference in cost.

[202] Additional labor costs are an estimate.

[203] Calculated from ResStock, 15 minute interval data by end use for Illinois, as provided by NREL.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY AND FOSSIL FUEL SAVINGS

Non Fuel Switch Measures (electric baseline)

$\Delta kWh = AEC_{base} - IAEC_{ee}$

Where:

$IAEC_{ee}$ = Integrated Annual Energy Consumption of an induction cooktop[204] in kWh/yr

= Actual if IAEC is unknown, if unknown assume 111 kWh/yr[205].

$AEC_{baseElec}$ = Annual Energy Consumption of a baseline electric cooktop in kWh/yr

= $IAEC_{ee} * (Eff_{ee} / Eff_{base})$

= If values unknown, assume 111 * 0.85/0.77 = 122.5 kWh/yr

Eff_{ee} = cooking efficiency of the induction cooktop

= Actual. If unknown, assume 85%[206].

Eff_{base} = cooking efficiency of baseline cooktop

= Actual. If unknown, assume 77%[207] for electric resitance cooktop.

For example, a residential induction cooktop will replace an electric resistance cooktop. The annual energy consumption of the induction cooktop has not been measured. The electric savings are calculated below:

$\Delta kWh = AEC_{base} - IAEC_{ee}$

$IAEC_{ee} = 111$ kWh/yr

$AEC_{base} = 111 * (0.85 / 0.77)$

= 122.5 kWh/yr

$\Delta kWh = 122.5 – 111$

= 11.5 kWh/yr

Fuel switch measure (baseline is natural gas cooktop):

Fuel switch / electrification measures must produce positive total energy savings (i.e., reduction in Btus at the premises) in order to qualify. This is determined as follows:

ΔSiteEnergySavings (MMBtu) = [GasConsumptionReplaced] – [ElectricConsumptionAdded]

= $[AEC_{baseGas} /10] – [IAEC_{ee} * 3,412/1,000,000]$

[204] The energy measurements are performed at an ISO/IEC 17025 accredited lab as specified in the application process for the ENERGY STAR Emerging Technology Award. Approved products on the ENERGY STAR Qualified Products List have IAEC values listed.

[205] Average Integrated Annual Energy Consumption (IAEC) of an induction cooktop on the ENERGY STAR Emerging Technology Award Qualified Products List, accessed June 2022, is 111kWh.

[206] The cooking efficiencies of electric resistance, gas, and induction cooktops are tested and calculated in the *Residential Cooktop Performance and Energy Comparison Study* conducted by Frontier Energy.

[207] Ibid

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

Where:

$IAEC_{ee}$ = Integrated Annual Energy Consumption of an induction cooktop[208] in kWh/yr

If actual IAEC is unknown, assume a value of 125 kWh/yr[209].

$AEC_{baseGas}$ = Annual Energy Consumption of a baseline gas cooktop in therms/yr

= $IAEC_{ee}$ * (Eff_{ee} / Eff_{base}) * 3412/100,000

= If values unknown, assume 111 * 0.85/0.32 * 3412/100,000 = 10.1 therms

Eff_{ee} = cooking efficiency of the induction cooktop

= Actual. If unknown, assume 85%[210].

Eff_{base} = cooking efficiency of baseline cooktop

= Actual. If unknown, assume 32%[211] for gas cooktop.

[208] The energy measurements are performed at an ISO/IEC 17025 accredited lab as specified in the application process for the ENERGY STAR Emerging Technology Award. Approved products on the ENERGY STAR Qualified Products List have IAEC values listed.

[209] Minimum annual energy consumption (AEC) of an induction cooktop to satisfy DOE's requirements for an ENERGY STAR Emerging Technology Award, 125 kWh/yr.

[210] The cooking efficiencies of electric resistance, gas, and induction cooktops are tested and calculated in Frontier Energy, July 2019; *Residential Cooktop Performance and Energy Comparison Study*.

[211] Ibid

Fuel switch example: a residential induction cooktop will replace a natural gas cooktop. The annual energy consumption of the induction cooktop has not been measured. The savings for a measure supported by an electric utility are calculated below:

ΔSiteEnergySavings (MMBtu) = [GasConsumptionReplaced] – [ElectricConsumptionAdded]

= [AEC_{base} /10] – [$IAEC_{ee}$ * 3,412/1,000,000]

= [10.1/10] – [111 * 3412/1000000]

= 1.01 – 0.378

=0.632 MMBtu

ΔkWh = ΔSiteEnergySavings * 1,000,000 / 3,412

= 0.632 * 1000000/3412

= 185 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Annual kWh savings from measure as calculated above.

Hours = Annual operating hours[212]

= 239 hours

CF = Summer Peak Coincidence Factor

= 29% [213]

FOSSIL FUEL SAVINGS

Calculation provided together with Electric Energy Savings above.

WATER AND OTHER NON-ENERGY 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 fossil fuel to electric.

For the purposes of forecasting load reductions due to fuel switch 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

[212] Assuming 1 hours per cycle and 239 cycles per year therefore 239 operating hours per year. 239 cycles per year is based on a 2016 CASE study for PG&E modeling Plug Loads.

[213] Calculated from ResStock, 15 minute interval data by end use for Illinois, as provided by NREL.

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 "Fossil Fuel Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Gas Cooking Consumption Replaced]

= $AEC_{baseGas}$

ΔkWh = [Electric Cooking Consumption Added]

= - $IAEC_{ee}$

MEASURE CODE: RS-MSC-INDC-V01-230101

REVIEW DEADLINE: 1/1/2025

5.1.15 Residential Bolt-On Smart Dryer Sensor

Description

This measure relates to the installation of a bolt-on smart wifi enabled dryer sensor with cloud data storage access on a residential gas-fired or electric dryer. A smart dryer sensor is an add-on device, which turns any residential dryer into a smart dryer. The device consists of

1) a sensor that detects temperature and humidity in the dryer
2) a connected hub with a built-in auto shut-off mechanism

The sensor monitors the temperature and humidity inside the clothes dryer to determine when a load is dry. When the humidity levels in the dryer fall below a pre-set cut-off at steady state, the device determines that a load is dry. The sensor then notifies the connected auto shut-off mechanism, cutting off power to the dryer and turning it off.

Residential clothes dryers have not changed significantly in their operation for many years. They typically offer either a time-dry setting (which uses a set timer) or an auto-dry setting (which uses a built-in moisture sensor to determine when the clothes are dry). Most built-in manufacturer moisture sensors do not work well and users tend to predominantly use the time-dry setting. This measure does not apply to dryers with coin operated mechanical timers, laundromat facilities or commercial clothes dryers. This measure was developed to be applicable to the following program types: TOS, RF, NC, DI and KITS.

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

Definition of Efficient Equipment

Natural gas-fired or electric resistance dryers with a residential bolt-on smart dryer sensor installed.

Definition of Baseline Equipment

The base case equipment is a conventional gas-fired or electric resistance residential dryer without a bolt-on smart dryer sensor installed. The dryer may have an built-in moisture sensor installed. The gas-fired dryer has a natural gas fuel-fired burner element and an electric powered drum motor.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be same as that of the clothes dryer, which is 16 years.[214]

Deemed Measure Cost

The deemed measure cost is $60 for a new residential bolt-on smart dryer sensor when installed on a gas-fired dryer. This applies to a non-intrusive bolt-on sensor installed with a magnetically attachable sensor inside the drum and a wirelessly connected plug with an auto shut-off.[215]

When attached to an electric dryer the deemed measure cost is $150[216].

Actual costs should be used when available or if the smart sensor setup is different from the above.

Loadshape

Loadshape R17 - Residential Electric Dryer

[214] Based on DOE Rulemaking Technical Support Document, LCC Chapter, 2011, as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018.
[215] Based on Nicor Gas ETP field demonstration of Residential IoT Smart Dryer Sensors.
[216] Based on current market cost for TickleStar DryerSaver Model #TS2201.

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For all dryers, please use the following equation for calculating energy savings, related to the motor:

ΔkWh_{motor} = N_{cycles} * ($Motor_{runtimesavings}$)* $Motor_{kW}$

Where:

N_{cycles} = Number of dryer cycles per year. Use actual data if available. If unknown,

= 283 cycles per year.[217]

$Motor_{runtimesavings}$ = 0.39 hrs/load[218]

$Motor_{kW}$ = Rated electric power draw of drum motor. Use actual nameplate data. If unknown,

= 0.25 kW.[219]

For electric resistance dryers, please use the following equation for calculating energy savings, related to the heating element:

$\Delta kWh_{heating}$ = N_{cycles} * RunTimeSavings * Dryer Draw Rate / 1,000

RunTimeSavings = Runtime savings for dryer heating element

= 0.08 hrs/load[220]

Dryer Draw Rate = Draw of electric resistance dryer heaters. Use actual nameplate data if available. If unknown,

= 5,250 Watts.[221]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

For gas-fired dryers:

= ΔkWh_{motor}

[217] Appendix D to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Dryers.
[218] Average data based on Nicor Gas ETP field demonstration of Residential IoT Smart Dryer Sensors. Please see Analysis file.
[219] Average Residential dryer drum motors, which typically range between 200 W and 300 W. Please see ENERGY STAR Scoping Reporting for Residential Clothes Dryers file, Table 2, page 3.
[220] Average data based on Nicor Gas ETP field demonstration of Residential IoT Smart Dryer Sensors. Based on natural-gas fired dryer data, and assuming similar savings will be seen for electric dryer.
[221] Average Residential electric resistance heaters typically draw about 5,000 - 5,500 watts. Please see ENERGY STAR Scoping Reporting for Residential Clothes Dryers file, Table 2, page 3.

For electric dryers:

= ΔkWh_{motor} + ΔkWh_{motor}

Hours = Annual run hours of clothes dryer. Use actual data, if available.

If unknown, use:

= 283 hours per year.[222]

CF = Summer Peak Coincidence Factor for measure

= 3.8%[223]

FOSSIL FUEL SAVINGS

For natural gas-fired dryers, please use the following eqution for calculating energy savings:

$\Delta Therm$ = N_{cycles} * $Therm_{convert}$ * RunTimeSavings * Dryer Firing Rate

Where:

N_{cycles} = Number of dryer cycles per year. Use actual data, if available.

If unknown, use:

= 283 cycles per year.[224]

$Therm_{convert}$ = Conversion factor from Btu to Therm

= 0.00001

RunTimeSavings = Runtime savings for gas dryer burner element

= 0.08 hrs/load[225]

Dryer Firing Rate = Firing rate of the natural gas-fired dryer burner. Use actual nameplate data, if available.

If unknown, use:

= 22,500 Btu/hr.[226]

For example, A single-family home in Chicago is retrofitting a residential bolt-on smart dryer sensor on a 22,500 Btu/hr natural gas-fired dryer with 400 loads annually. The annual savings for the installation would be:

Electric Energy Savings

= 400 x 0.39 x 0.25

= 39 kWh

Natural Gas Savings

= 400 x 0.00001 x 0.08 x 22,500

= 7.2 therms

[222] ENERGY STAR qualified dryers have a maximum test cycle time of 80 minutes. Assume one hour per dryer cycle from existing TRM measure 5.1.10.

[223] Based on coincidence factor of 3.8% for clothes washers from existing Illinois TRM measure 5.1.10.

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

[225] Average data based on Nicor Gas ETP field demonstration of Residential IoT Smart Dryer Sensors. See Analysis file for details.

[226] Residential dryer burners typically range between 20,000 Btu/hr – 25,000 Btu/hr. Please see ENERGY STAR Scoping Reporting for Residential Clothes Dryers file, Table 2, page 3.

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-SCDS-V01-230101

REVIEW DEADLINE: 1/1/2025

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.[227]

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.[228]

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%.[229]

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

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

[229] 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[230]

ISR = In Service Rate, dependent on delivery mechanism

Delivery Mechanism	ISR
Multifamily Energy Efficiency Kit, Leave behind	40%[231]
Single Family Energy Efficiency Kit, Leave behind	55%[232]
Income Qualified Energy Efficiency Kit, Mailed	69%[233]
Community Distributed Kit	91%[234]
Direct Install	100%
Time of Sale	71%[235]

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

[230] 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.
[231] 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.
[232] Research from 2018 ComEd Home Energy Assessment participant survey.
[233] Research from 2021 Ameren Illinois Income Qualified participant survey (customer self-report), available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf
[234] Research from 2018 Ameren Illinois Income Qualified participant survey.
[235] Research from 2019 ComEd Appliance Rebate Program- Online Marketplace participant survey

# Plugs	Delivery Mechanism	ΔkWh
	Income Qualified Energy Efficiency Kit, Mailed	39.0
	Community Distributed Kit	51.4
	Direct Install	56.5
	Time of Sale	40.1
7-plug	Multifamily Energy Efficiency Kit, Leave behind	41.2
	Single family Energy Efficiency Kit, Leave behind	56.7
	Income Qualified Energy Efficiency Kit, Mailed	71.1
	Community Distributed Kit	93.8
	Direct Install	103.0
	Time of Sale	73.1
Unknown[236]	Multifamily Energy Efficiency Kit, Leave behind	31.9
	Single family Energy Efficiency Kit, Leave behind	43.9
	Income Qualified Energy Efficiency Kit, Mailed	55.0
	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 [237]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [238]

# Plugs	Delivery Mechanism	ΔkW
5- plug	Multifamily Energy Efficiency Kit, Leave behind	0.0025
	Single family Energy Efficiency Kit, Leave behind	0.0035
	Income Qualified Energy Efficiency Kit, Mailed	0.0044
	Community Distributed Kit	0.0058

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

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

[238] 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.

# Plugs	Delivery Mechanism	ΔkW
	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
	Income Qualified Energy Efficiency Kit, Mailed	0.0080
	Community Distributed Kit	0.0105
	Direct Install	0.0116
	Time of Sale	0.0082
Unknown[239]	Multifamily Energy Efficiency Kit, Leave behind	0.0036
	Single family Energy Efficiency Kit, Leave behind	0.0049
	Income Qualified Energy Efficiency Kit, Mailed	0.0062
	Community Distributed Kit	0.0081
	Direct Install	0.0090
	Time of Sale	0.0064

FOSSIL FUEL SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-CEL-SSTR-V08-230101

REVIEW DEADLINE: 1/1/2025

239 Calculated as average of 5 and 7 plug savings assumptions.

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

DESCRIPTION

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

By utilizing advanced control strategies such as a countdown timer, external sensors (e.g. of infra-red remote usage and/or occupancy sensors, true RMS (Root Mean Square) power sensing; both active power loads and standby power loads of controlled devices are managed by Tier 2 AV APS devices.[240] 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.[241]

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.

[240] 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.

[241] 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.[242]

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%.[243]

[242] 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.

[243] 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%[244]
Infrared and Occupancy Sensor	25%[245]

$BaselineEnergy_{AV}$ = 466 kWh[246]

ISR = In Service Rate.

Product Type	ISR[247]
Infrared Only	73%
Infrared and Occupancy Sensor	83%

Deemed savings for each product type are provided below:

---

244 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%).

245 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%)

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

247 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 [248]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [249]

Deemed savings for each product type are provided below:

Product Type	ΔkW
Infrared Only	0.0249
Infrared and Occupancy Sensor	0.0177

FOSSIL FUEL SAVINGS

N/A[250]

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

[248] 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.
[249] 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.
[250] Interactive effects of Tier 2 APS on space conditioning loads has not yet been adequately studied.

5.2.3 ENERGY STAR Television

DESCRIPTION

An ENERGY STAR Certified television installed in place of a standard televion.

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 equipment is defined as a television meeting the ENERGY STAR Version 9.0.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is defined as a non ENERGY STAR certified television.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of this measure is 5 years.[251]

DEEMED MEASURE COST

The incremental cost for this measure is $60.[252]

LOADSHAPE

R13: Residential Standby Losses - Entertainment

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 22%[253]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ENERGY STAR savings summarized in table below[254]

Equipment Size Bin	ΔkWh
<=47.5"	93.2

[251] ‘ENERGY STAR Version 9.0 TVs Data Package.xls’.
[252] Estimate from ‘Savings Estimation Technical Reference Manual, 2017’. Highest cost estimate due to majority of TVs now being the larger bin sizes. This estimate is an old reference and would benefit a new study to improve the assumption.
[253] Based upon Hawai'i Energy, Technical Reference Manual, 2018
[254] ‘ENERGY STAR Version 9.0 TVs Data Package.xls’.

Equipment Size Bin	ΔkWh
47.5"<x<=52.5"	91.3
52.5"<x<=59.5"	71.6
59.5"<x<=69.5"	75.3
69.5"<x<=80"	31.7

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / Hours * CF

Where:

Hours = Estimate of hours savings achieved.

= 1759[255]

CF = Coincidence Factor

= 0.22[2]

Equipment Size Bin	ΔkW
<=47.5"	0.01166
47.5"<x<=52.5"	0.01142
52.5"<x<=59.5"	0.00896
59.5"<x<=69.5"	0.00942
69.5"<x<=80"	0.00396

FOSSIL FUEL 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-CEL-TVS-V01-230101

REVIEW DEADLINE: 1/1/2025

[255] Most savings are achieved during "automatic brightness control" during active viewing. Recent study Nielsen "State of Play" found average viewing of 4.82 hours per day = 1759 hours per year.

5.3 HVAC End Use

5.3.1 Centrally Ducted 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 prescriptive measure does not apply to known installations where existing fuel-fired heating systems remain in place to provide back up heat at low temperatures ("hybrid systems"). Savings from such installations should be calculated on a custom basis if done outside of midstream type offerings where installation details are tracked.

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 allocation 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 allocation 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).[256]
   - 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

[256] 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.

assumptions.

A weighted average early replacement rate is provided for use in downstream programs when the actual baseline early replacement rates are unknown.

Deemed Early Replacement Rates For ASHP

	Deemed Early Replacement Rate
Early Replacement Rate for downstream ASHP participants	36%[257]

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.

The following conversion factors are recommended for use if the efficient equipment is not rated under the new testing procedure:[258]

SEER = SEER2 / X

EER = EER2 / X

HSPF = HSPF2 / X

Where:

X	SEER	EER	HSPF
Ducted	0.95	0.95	0.91

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.[259]

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.[260]

Note: New Federal Standards affecting heat pumps become effective January 1, 2023. The new standards effective in 2023, require any residential heat pump manufactured in, or imported into, the United States to have a minimum

[257] Based on ComEd program data from 2018-2020 (444 ASHP installs).

[258] Consortium for Energy Efficiency (CEE), Testing, Testing, M1, 2, 3, Transitioning to New Federal Minimum Standards, CEE Summer Program Meeting, June 10, 2022.

[259] 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'.

[260] 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'.

efficiency rating meeting the following:[261]

- Split system heat pump – 14.3 SEER2 and 7.5 HSPF2
- Single-package heat pump – 13.4 SEER2 and 6.7 HSPF2

These new federal standards will be adopted by the program, beginning 1/1/2024. For the 2023 program year, the baseline equipment efficiencies are detailed in this section by replacement scenario.

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[262].

Unit Type	Efficiency Standard
ASHP	14 SEER, 11 EER, 8.2 HSPF
Electric Resistance	3.412 HSPF
Natural Gas or LP Furnace	80% AFUE
Natural Gas or LP Boiler	84% AFUE
Oil Furnace	83% AFUE
Oil Boiler	86% AFUE
Central AC	13 SEER, 10.5 EER
Unknown [263]	13.52 SEER, 10.75EER, 6.25 HSPF, 80.1% AFUE

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).

When unknown, default early replacement efficiency assumptions are 9.70 SEER, 7.83 EER, 5.24 HSPF and 80% AFUE. Consistent with TRM Volume 1 Section 2.3.1 for midstream programs or other cases where the existing condition is unknown, it may be appropriate to apply a deemed percent split of Time of Sale and Early Replacement assumptions based on evaluation results

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years.[264]

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

[261] The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2, EER2, and HSPF2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system heat pumps are 15 SEER and 8.8 HSPF and for single-package heat pumps are 14 SEER and 8 HSPF, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservations Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048 (https://www.regulations.gov/document/EERE-2014-BT-STD-0048-0200)
[262] Federal Standard as provided in DOE 10 CFR 430.32.
[263] Values represent the weighted average [SEER/EER/HSPF/AFUE] baseline values reflecting the assumed shares of installed ASHP replacing given baseline technologies (e.g. ASHP/electric resistance or furnace/boiler) by fuel type. Assumed shares are based on Opinion Dynamics and Guidehouse analysis of 2018-2021 Ameren and ComEd HVAC (downstream) program tracking data. For further details, see '2018-2021 AIC Res HVAC Data ASHP Baseline TRM Update 2022-07-11.xls'.
[264] Based on 2016 DOE Rulemaking Technical Support document, as recommended in Guidehouse 'ComEd Effective Useful Life Research Report', May 2018.

for boilers[265] and 16 years for electric resistance.[266]

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 ($6562 + $600 per ton for a new baseline ASHP[267], $2,011 for a new baseline 80% AFUE furnace or $4,053 for a new 84% AFUE boiler[268] and $952 per ton for new baseline Central AC replacement[269]).

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 the appropriate number of years described above in the 'Deemed Lifetime of Efficient Equipment' section) of replacing existing equipment with a new baseline unit is assumed to be $7,527 + $688 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.[270] 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);[271]

Efficiency (SEER)	Full Efficient ASHP Cost (including labor)
14.5	$6,685 + $600/ ton
15	$6,865 + $600/ ton
16	$7,000 + $600/ ton
17	$7,286 + $600/ ton
18	$7,495 + $600/ ton
19	$7,720 + $600/ ton
20	$7,946 + $600/ ton

Fuel switch scenarios are likely to require additional installation work which may include adding new electrical circuits, capping existing gas lines and upgrading electrical panels. These costs are likely to range significantly and actual values should be used wherever possible. If unknown, assume an additional $2,000 for fuel switch installations.

Quality Installation: The additional design and installation work associated with quality installation has been estimated to cost an additional $150.[272]

LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling

265 Assumed to be one third of effective useful life of replaced equipment.
266 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.
267 Full install ASHP costs are based upon data provided by Ameren. See 'ASHP Costs_06242022'. Efficiency cost increment consistent with Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016 study results.
268 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.
269 Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator.
270 All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.98%.
271 Full install ASHP costs are based upon data provided by Ameren. See 'ASHP Costs_06242022'. Efficiency cost increment consistent with Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016 study results.
272 Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers in Iowa.

COINCIDENCE FACTOR

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

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

= 72%[273]

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

= 46.6%[274]

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

= 67%[275]

$CF_{PJM,\ MF}$ = 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 FOSSIL FUEL SAVINGS

Non fuel switch measures:

$\Delta kWh_{Non\ Fuel\ Switch}$ = ((CoolingLoad * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$)))) / 1000) + ((HeatLoad * (1/(HSPF_base * HSPF_ClimateAdj * (1 – $DeratingHeat_{Base}$)) - 1/(HSPF_ee * HSPF_ClimateAdj * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) / 1000)

Fuel switch measures:

Fuel switch measures must produce positive total lifecycle energy savings (i.e., reduction in Btus at the premises) in order to qualify. This is determined as follows:

SiteEnergySavings (MMBTUs) = FuelSwitchSavings + NonFuelSwitchSavings

FuelSwitchSavings = GasHeatReplaced – ASHPSiteHeatConsumed

[273] 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)'.
[274] 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.
[275] Multifamily coincidence factors both from; *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015

NonFuelSwitchSavings = FurnaceFanSavings + ASHPSiteCoolingImpact

Where:

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

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

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

ASHPSiteCoolingImpact = ((CoolingLoad * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) - 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, 7 years for furnace, 8 years for boilers, 16 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.

Programs where existing system unknown

In programs where the existing fuel or system type is unknown, savings should be apportioned between the Fuel Switch and Non- Fuel Switch scenarios, as follows:

Savings from Non-Fuel Switch (kWh) = (1 – %FuelSwitch) * $\Delta kWh_{Non\ Fuel\ Switch}$

Plus

Savings from Fuel Switch (MMBtu converted to appropriate fuel as table above)

= %FuelSwitch * SiteEnergySavings (MMBTUs)

Where:

%FuelSwitch = The percentage of replacements resulting in fuel-switching.

= 1 when fuel switching is known, 0 if non fuel switch

= when unknown, e.g. midstream program, determine via evaluation

CoolingLoad = Annual cooling load for the building

= FLH_cooling * Capacity_ASHPcool

FLH_cooling = Full load hours of air conditioning

= dependent on location:

Climate Zone (City based upon)	FLH_cooling (single family) [276]	FLH_cooling (multifamily) [277]
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820
Weighted Average[278]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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)

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,[279] 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	9.7[280]	14[281]	
Central AC	9.7[282]	13[283]	

[276] 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.

[277] Ibid.

[278] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

[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'

[281] Minimum Federal Standard as of 1/1/2015

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

[283] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

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
No central cooling	Make '1/SEER_exist' = 0 [284]	13[285]	
Unknown [286]	9.7	13.52	

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

= Actual.

SEERadj = Adjustment percentage to account for in-situ performance of variable speed units[287]

= $[(0.805 \times \left(\frac{EER_{ee}}{SEER_{ee}}\right) + 0.367]$ if variable speed or unknown

= 1 if single speed

$DeratingCool_{Eff}$ = Efficent ASHP Cooling derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown[288]

$DeratingCool_{Base}$ = Baseline Cooling derating

= 10%

HeatLoad = Annual heat load for the building (Btus)

= FLH_ASHPheat * Capacity_ASHPheat

FLH_ASHPheat = Full load hours of heat pump heating

= Dependent on location and home type:

Climate Zone (City based upon)	FLH_heat (single family and multifamily)[289]
1 (Rockford)	1,969

[284] 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.

[285] Assumes that the decision to replace existing systems includes desire to add cooling.

[286] Values represent the weighted average SEER baseline values reflecting the assumed shares of installed ASHP replacing given baseline technologies (e.g. ASHP/electric resistance or furnace/boiler) by fuel type. Assumed shares are based on Opinion Dynamics and Guidehouse analysis of 2018-2021 Ameren and ComEd HVAC (downstream) program tracking data. For further details, see '2018-2021 AIC Res HVAC Data ASHP Baseline TRM Update 2022-07-11.xls'.

[287] 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'.

[288] 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.

[289] 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

Climate Zone (City based upon)	FLH_heat (single family and multifamily)[289]
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[290]	
ComEd	1,846
Ameren	1,612
Statewide	1,821

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 Seasonal 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,[291] 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	5.78[292]	8.2[293]	
Electric Resistance	3.41[294]		
Unknown [295]	5.24	6.25	

HSPF_ee = Heating Seasonal Performance Factor of efficient Air Source Heat Pump (kBtu/kWh)

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.

290 Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

291 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).

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

293 Based on Minimum Federal Standard effective 1/1/2015.

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

295 Values represent the weighted average HSPF baseline values reflecting the assumed shares of installed ASHP replacing given baseline technologies (e.g. ASHP/electric resistance or furnace/boiler) by fuel type. Assumed shares are based on Opinion Dynamics and Guidehouse analysis of 2018-2021 Ameren and ComEd HVAC (downstream) program tracking data. For further details, see '2018-2021 AIC Res HVAC Data ASHP Baseline TRM Update 2022-07-11.xls'.

= Actual or 8.5 if unknown[296]

HSPFadj = Adjustment percentage to account for the heating capacity ratio of the efficient variable speed unit[297]

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

= Actual using AHRI lookup values for efficient unit heating capacities rated at 17°F and 47°F. If not available or if single speed, assume 1.[298]

$DeratingHeat_{Eff}$ = Efficent ASHP Heating derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed[299]

$DeratingHeat_{Base}$ = Baseline Heating derating

= 10%

HSPF_ClimateAdj = Adjustment factor to account for observed discrepency between seasonal heating performance relative to rated HSPF as provided by standard AHRI 210/240 rating conditions. Note, the adjustment is dependent on the test method use for the rating (i.e. HSPF or HSPF2 rating) [300]:

City (county based upon)	HSPF_ClimateAdj When using HSPF rating	HSPF_ClimateAdj When using HSPF2 rating
1 (Rockford)	70%	77%
2 (Chicago)	70%	77%
3 (Springfield)	83%	91%
4 (Belleville)	83%	91%
5 (Marion)	83%	91%
Weighted Average[301]		
ComEd	70%	77%
Ameren	81%	89%
Statewide	73%	80%

296 ENERGY STAR minimum.

297 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'.

298 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.

299 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.

300 Adjustment factors are based on findings from NEEA, July 2020 'EXP07:19 Load-based and Climate-Specific Testing and Rating Procedures for Heat Pumps and Air Conditioners'. See 'NEEA HP data' for calculation. Findings were consistent with other reviewed sources including ASHRAE, 2020 'Right-Sizing Electric Heat Pump and Auxiliary Heating for Residential Heating Systems Based on Actual Performance Associated with Climate Zone' and Cadmus, 2022 'Residential ccASHP Building Electrification Study'. The difference between HSPF and HSPF2 ratings is based on the change in testing procedure that will correct for some of this effect where ducted systems will have an approximately 9% lower HSPF2 rating as compared to HSPF, based on CEE presentation, July 2022, 'Testing Testing, M1, 2, 3: Transitioning to New Federal Minimum Standards'.

301 Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

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,[302] or if unknown assume default:

Baseline/ Existing Heating System	AFUEbase		
	Early Replacement (Remaining useful life of existing equipment)[303]	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Furnace	64.4%	80%	80%
Boiler	61.6%	84%	84%
Unknown [304]	80%	80.1%	80.1%

FurnaceFlag = 1 if system replaced is a fossil fuel 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%[305]

For New Construction, Time of Sale and early replacement (remaining 10 years) F_e_New = 1.88%[306]

3412 = Btu per kWh

%IncentiveElectric = % of total incentive paid by electric utility

= Actual

%IncentiveGas = % of total incentive paid by gas utility

= Actual

[302] 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).

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

[304] Values represent the weighted average AFUE baseline values reflecting the assumed shares of installed ASHP replacing given baseline technologies (e.g. ASHP/electric resistance or furnace/boiler) by fuel type. Assumed shares are based on Opinion Dynamics and Guidehouse analysis of 2018-2021 Ameren and ComEd HVAC (downstream) program tracking data. For further details, see '2018-2021 AIC Res HVAC Data ASHP Baseline TRM Update 2022-07-11.xls'.

[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.

[306] 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

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 * 0.83 * (1 – 0.1)) - 1/(9 * 0.83 * 1.001 * (1-0)))) / 1000)

= 1,677 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 * 0.83 * (1-0.1)) - 1/(9 * 0.83 * 1.001 * (1-0)))) / 1000)

= 6,269 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 * 0.83 * (1 – 0.1)) - 1/(9 * 0.83 *1.001 * (1-0)))) / 1000)

= 1,677 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 * HSPF_ClimateAdj * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) /1000 * 3412)/ 1,000,000

= ((1,288 * 33,000 * (1/(9 * 0.83 * 1.001 * (1-0)))) / 1000 * 3412)/ 1,000,000

= 19.4 MMBtu

Fuel Switch Illustrative Example continued

ASHPSiteCoolingImpact = ((CoolingLoad * (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 – 19.4 + 2.1 = 36.8 MMBtu [Measure is eligible]

Savings would be claimed as follows:

Measure supported by:	Electric Utility claims:	Gas Utility claims:
Electric utility only	36.8 * 1,000,000/3412 = 10,785 kWh	N/A
Electric and gas utility	0.5 * 36.8 * 1,000,000/3412 = 5,393 kWh	0.5 * 36.8 * 10 = 184 Therms
Gas utility only	N/A	36.8 * 10 = 368 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 * HSPF_ClimateAdj * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) /1000 * 3412)/ 1,000,000 * 16 years

= ((1,288 * 33,000 * (1/(9 * 0.83 * 1.001 * (1-0)))) / 1000 * 3412)/1,000,000 * 16

= 310.3 MMBtu

Fuel Switch Illustrative Example continued

LifetimeASHPSiteCoolingImpact = ((($CoolingLoad * (1/(SEER\_exist * (1 – DeratingCool_{Base})) - 1/(SEER\_ee * SEERadj * (1 – DeratingCool_{Eff}))))/1000 * 3412)/1,000,000 * 6$ years) + ((($CoolingLoad * (1/(SEER\_base * (1 – DeratingCool_{Base})) - 1/(SEER\_ee * SEERadj * (1 – DeratingCool_{Eff}))))/1000 * 3412)/1,000,000 * 10$ 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 – 310.3 + 55.4 = 695 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 = (($HeatLoad * (1/(HSPF\_ee * HSPF\_ClimateAdj * HSPFadj * (1 – DeratingHeat_{Eff}))))$ /1000 * 3412)/ 1,000,000

= ((1,288 * 33,000 * (1/(9 * 0.83 * 1.001 * (1-0)))) / 1000 * 3412) / 1,000,000

= 19.4 MMBtu

ASHPSiteCoolingImpact = (($CoolingLoad * (1/(SEER\_exist * (1 – DeratingCool_{Base})) - 1/(SEER\_ee * SEERadj * (1 – DeratingCool_{Eff}))))/1000 * (FirstYearH_{grid} * (1 + ElectricT\&D))$ / 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 – 19.4 + 5.7 = 54.4 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 * 0.83 * 1.001 * (1-0)))) / 1000 * 3412) / 1,000,000

= 19.4 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 – 19.4 + 2.1 = 37.0 MMBtu

Savings would be claimed as follows:

Measure supported by:	Electric Utility claims:	Gas Utility claims:
Electric utility only	First 6 years: 54.4 * 1,000,000/3412 = 15,944 kWh Remaining 10 years: 37.0 * 1,000,000/3412 = 10,844kWh	N/A
Electric and gas utility	First 6 years: 0.5 * 54.4 * 1,000,000/3412 = 7,972 kWh Remaining 10 years: 0.5 * 37.0 * 1,000,000/3412 = 5,422 kWh	First 6 years: 0.5 * 54.4 * 10 = 272 Therms Remaining 10 years: 0.5 * 37.0 * 10 = 185 Therms
Gas utility only	N/A	First 6 years: 54.4 * 10 = 544 Therms Remaining 10 years: 37.0 * 10 = 370 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.[307] If unknown, assume default provided below:

[307] 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	7.83[308]	11.0[309]	
Central AC	7.83[310]	10.5[311]	
No central cooling	Make '1/EER_exist' = 0 [312]	10.5[313]	
Unknown [314]	7.83	10.75	

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

= Actual. If unknown, assume 12.5 EER.[315]

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

= 72%[316]

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

= 46.6%[317]

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

= 67%[318]

$CF_{PJM,\ MF}$ = 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

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

[309] 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'.

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

[311] 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'.

[312] 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.

[313] Assumes that the decision to replace existing systems includes desire to add cooling.

[314] Program tracking data does not provide an EER value. These are estimated based on the other values in the table.

[315] ENERGY STAR minimum.

[316] 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)'.

[317] 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.

[318] *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

Fossil Fuel 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 fossil fuel 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), 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, should therefore reflect the decrease in one fuel and increase in another, as opposed to the single savings value calculated in the "Electric and Fossil Fuel Energy Savings" section 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, 7 years for furnace, 8 years for boilers or GSHP, 16 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]

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

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

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

MEASURE CODE: RS-HVC-ASHP-V12-230101

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.[319]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 13 years.[320] 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.[321] For foam pipe insulation assume a measure cost of $0.26/ft for ½" insulation and $0.31/ft for ¾" insulation.[322]

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[319] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[320] 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.
[321] Consistent with DEER 2008 Database Technology and Measure Cost Data.
[322] Review of website cost data for Homedepot.com, Lowes.com, and Menards.com for locations in Peoria, IL.

FOSSIL FUEL 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[323])

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)[324]

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

= 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:[325]

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[326]	
ComEd	1,846
Ameren	1,612
Statewide	1,821

ΔT = Average temperature difference between circulated heated water and unconditioned

[323] Where possible it should be ensured that the R-value of the insulation is at the appropriate mean rating temperature (125F).

[324] 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.

[325] 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.

[326] Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

space air temperature (°F) [327]

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[328]	125	85

ηBoiler = Efficiency of boiler

= 0.819 [329]

Parameter assumptions for various pipe sizes and materials:

Type and Size	C_{Inside}[330] (I.D.*π/12) (ft)	Product of Overall Heat Transfer Coefficient and Pipe Area (UA) per foot[331] from bare pipe (BTU/hr·ft·°F)	Pipe Area per linear foot (ft^3)[332]	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

[327] 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).

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

[329] Average efficiency of boiler units found in Ameren PY3-PY4 data.

[330] 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.

[331] Laboratory measured values from Hoeschele and Weitzel (2012), Figure 1.

[332] Calculated using the average pipe thickness (I.D. + O.D.)*0.5.

Mid-Life adjustment

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

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

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 13 years.[333] 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-V06-230101

REVIEW DEADLINE: 1/1/2025

333 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).[334]
   - 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 in downstream programs when the actual baseline early replacement rate is unknown.[335]

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 downstream participants when a CAC unit when the CAC unit is the Primary unit in a CSR project	14%
Early Replacement Rate for downstream participants when 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

[334] 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.

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a ducted split central air conditioning unit meeting at least the minimum ENERGY STAR version 5.0 efficiency level standards; 15 SEER and 12.5 EER.

Note: New ENERGY STAR specifications affecting heat pump and central air conditioners, v6.1, becomes effective January 1, 2023. The new specifications require central air conditioners to meet the following minimum efficiency requirements:[336]

- Split system central air conditioners – 15.2 SEER2 and 12.0 EER2
- Single package central air conditioners – 15.2 SEER2 and 11.5 EER2

The measure characterization recommends sourcing the efficiency specifications from the actually installed equipment. If those values are not known, the default equipment efficiency recommendations are conservatively based on ENERGY STAR version 5.0 specifications.

The following conversion factors are recommended for use if the efficient equipment is not rated under the new testing procedure:[337]

SEER = SEER2 / X

EER = EER2 / X

Where:

X	SEER	EER
Ducted	0.95	0.95
Packaged	0.95	0.95

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.[338] Consistent with TRM Volume 1 Section 2.3.1 for midstream programs or other cases where the existing condition is unknown, it may be appropriate to apply a deemed percent split of Time of Sale and Early Replacement assumptions based on evaluation results

Note: New Federal Standards affecting central air conditioners become effective January 1, 2023. The new standards

[336] ENERGY STAR Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment, v6.1, effective January 1, 2023, are in terms of an updated metric, depicted as SEER2 and EER2. The updated test method as well as the updated ENERGY STAR specifications mimic the updated federal appliance standards. An equivalent stringency of these new standards for split system air conditioners are 16 SEER and 13 EER and for single-package air conditioners are 16 SEER and EER 12, as detailed in: Consortium for Energy Efficiency (CEE) Residential HVAC Specifications, Estimated Appendix M1 Equivalents, January 15 2021

[337] Consortium for Energy Efficiency (CEE), Testing, Testing, M1, 2, 3, Transitioning to New Federal Minimum Standards, CEE Summer Program Meeting, June 10, 2022.

[338] Baseline SEER and EER should be updated when new minimum federal standards become effective.

effective in 2023, require any residential central air conditioner manufactured in, or imported into, the United States to have a minimum efficiency rating meeting the following:[339]

- Split system air conditioners – 13.4 SEER2
- Single-package air conditioners – 13.4 SEER2

These new federal standards will be adopted by the program, beginning 1/1/2024. For the 2023 program year, the baseline equipment efficiencies are detailed in this section by replacement scenario.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years.[340]

Remaining life of existing equipment is assumed to be 6 years.[341]

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below:[342]

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.[343]

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

[339] The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system air conditioners are 14 SEER and for single-package air conditioners are 14 SEER, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservations Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048 (https://www.regulations.gov/document/EERE-2014-BT-STD-0048-0200)

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

[341] Assumed to be one third of effective useful life

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

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

$3,140.[344] This cost should be discounted to present value using the nominal societal discount rate.

Quality Installation: The additional design and installation work associated with quality installation has been estimated to cost an additional $150.[345]

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%[346]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 46.6%[347]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

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

Early replacement:[348]

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:

---

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

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

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

347 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.

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

FLHcool = Full load cooling hours

= dependent on location and building type:[349]

Climate Zone (City based upon)	FLHcool (single family)	FLHcool (multifamily)	FLH_cooling (weatherized multifamily) [350]
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[351]			
ComEd	567	504	323
Ameren	810	734	470
Statewide	632	565	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.[352] If building type is unknown, assume 31,864Btu/hr.[353]

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

= 13 [354]

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

349 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.

350 *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.

351 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

352 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.

353 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.

354 Based on Minimum Federal Standard.

account for degradation over time,[355] or, if unknown, assume 9.3.[356]

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

= Actual, or 15 if unknown.

SEERadj = Adjustment percentage to account for in-situ performance of the unit[357]

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

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

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown[358]

$DeratingCool_{Base}$ = 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:

355 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).

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

357 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'.

358 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.

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

Early replacement:[359]

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

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

ΔkW for remaining measure life (next 12 years):

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

Where:

EERbase = EER Efficiency of baseline unit

= 10.5 [360]

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.[361] If unknown, assume 7.5.[362]

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%[363]

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

= 46.6%[364]

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359 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).

360 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’.

361 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).

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

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

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

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

Fossil Fuel Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-HVC-CAC1-V10-230101

Review Deadline: 1/1/2024

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).[365]

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.[366]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years.[367] 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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[365] 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

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

[367] 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%[368]

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

= 46.6%[369]

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[370]

SLF = Supply Loss Factor

= % leaks sealed located in Supply ducts * 1 [371]

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

[369] 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.

[370] 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).

[371] 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[372]

RLF = Return Loss Factor

= % leaks sealed located in Return ducts * 0.5[373]

Default = 0.25[374]

c) Calculate Electric Energy Savings:

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

$\Delta kWh_{cooling}$ = (($\Delta CFM25_{DL}$/ ((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)[375]

FLHcool = Full load cooling hours

= Dependent on location as below:[376]

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[377]	567	
ComEd	810	504

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'.

372 Assumes 50% of leaks are in supply ducts.

373 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'.

374 Assumes 50% of leaks are in return ducts.

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

376 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.

377 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily
Ameren	632	734
Statewide		565

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

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.4 for Semi-Conditioned Spaces[378]

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[379]	66%

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume the following:[380]

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 Fossil Fuel Savings

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

= 3.14%[381]

29.3 = kWh per therm

378 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.

379 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

380 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.

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

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

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

$CFM50_{Envelope\ Only}$ = 4500 CFM50

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

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

$CFM50_{Envelope\ Only}$ = 4500 CFM50

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

Duct Leakage:

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

= 387 CFM

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

= 139 CFM

Duct Leakage reduction at CFM25:

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

= 119 CFM25

Energy Savings:

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

= 237 + 195

= 432 kWh

<u>Heating savings for homes with electric heat:</u>

$\Delta kWh_{heatingElectric}$ = (($\Delta CFM25_{DL}$ /((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:[382]

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

[382] 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
Weighted Average[383]	
ComEd	1,846
Ameren	1,612
Statewide	1,821

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[384]

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[385], 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:[386]

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

383 Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

384 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.

385 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.

386 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
Resistance	N/A	N/A	1.00
Unknown (for use in program evaluation only)[387]	N/A	N/A	1.28

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:[388]

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[389]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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

387 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.

388 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.

389 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

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[390]

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[391]	66%

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume:[392]

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 *

[390] 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.

[391] 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

[392] 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.

%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:[393]

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[394]	
ComEd	1,846
Ameren	1,612
Statewide	1,821

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[395]

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[396], 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%

393 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.

394 Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

395 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.

396 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	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
NSG	8%	16%	35%	41%	20%
Nicor	8%	16%	35%	41%	20%
All DUs					**24%**

COP = Coefficient of Performance of electric heating system[397]

= Actual. If not available use:[398]

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)[399]	N/A	N/A	1.28

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:[400]

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397 Note that the HSPF of a heat pump is equal to the COP * 3.413.

398 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.

399 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.

400 Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using

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
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ComEd	567	504
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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%[402]

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

= 46.6%[403]

FOSSIL FUEL 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)[404]

FLHheat = Full load heating hours

=Dependent on location as below:[405]

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.

[401] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

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

[403] 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.

[404] 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.

[405] 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
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[406] ComEd Ameren Statewide	 1,846 1,612 1,821

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[407]

%GasHeat = Percent of homes that have gas space heating

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[408], 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%**

100,000 = Converts Btu to therms

ηEquipment = Heating Equipment Efficiency

[406] Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

[407] 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.

[408] 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.

= Actual.[409] If not available, use 83%.[410]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[411]

= Actual. If not available, use 70%[412]

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

$\Delta Therm = ((DE_{after} - DE_{before}) / DE_{after})) * FLHheat * InputCapacityHeat * TRFheat * \%GasHeat *$

[409] 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.

[410] 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

[411] 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.

[412] Estimated as follows: 0.829 * (1-0.15) = 0.70

(ηEquipment / ηSystem)) / 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 *

$(\eta Equipment / (\eta Equipment_{New} * DE_{after})) / 100,000$

Where:

$\eta Equipment_{New}$ = 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.[413] 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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[413] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

5.3.5 Furnace Blower Motor

Description

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.[414] 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.[415]

Deemed Measure Cost

The capital cost for this measure as a retrofit should be actual if known; if unknown, assume $350.[416] In cases of furnace early replacements, it is assumed the incremental cost of the ECM is $0.

---

[414] 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.

[415] 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

[416] The cost of a typical replacement motor is estimated at $180 based on quotes from online suppliers, plus $17 for the bracket. Typical labor costs are estimated at between $140 and $190 based on program experience provided by Staples in April 2022. A total retrofit measure cost is therefore estimated at $350.

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;[417] 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[418]

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* [419]
Rockford	247	229	210	223
Chicago	245	230	208	222
Springfield	249	231	203	221
Belleville	247	235	196	222

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

[418] 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'.

[419] 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* [419]
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[420]

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* [421]
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

[420] 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'.

[421] 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)

FOSSIL FUEL SAVINGS

$$\Delta therms^{422} = - HeatingkWhSavings * 0.03412 / AFUE$$

Where:

HeatingkWhSavings = Heating kWh savings per ton of cooling[423]

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.[424]

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

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REVIEW DEADLINE: 1/1/2026

422 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.

423 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'.

424 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).[425]
   - 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 in downstream programs when the actual baseline early replacement rates are unknown.[426]

Deemed Early Replacement Rates for Boilers

	Deemed Early Replacement Rate
Early Replacement Rate for downstream 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%

[425] 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.

[426] 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).[427]

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.[428]

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. Consistent with TRM Volume 1 Section 2.3.1 for midstream programs or other cases where the existing condition is unknown, it may be appropriate to apply a deemed percent split of Time of Sale and Early Replacement assumptions based on evaluation results

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[429]

Early replacement: Remaining life of existing equipment is assumed to be 8 years.[430]

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is dependent on tier:[431]

	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.[432] This cost should be discounted to present value using the nominal discount rate.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

[427] 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)
[428] Code of Federal Regulations, effective January 15, 2021 (10 CFR 432(e)(3)).
[429] Appendix 8-F of the Department of Energy Commercial Technical Support Document, Table 8.3.3, federal residential appliance standards.
[430] Assumed to be one third of effective useful life
[431] 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.
[432] $4,053 inflated using 1.91% rate.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

FOSSIL FUEL SAVINGS

Time of Sale:

$$\Delta Therms = (EFLH * CAP_{Input} * (AFUE_{Eff} / AFUE_{Base} - 1)) / 100{,}000$$

Early replacement:[433]

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[434]
1 (Rockford)	1022
2 (Chicago)	976
3 (Springfield)	836
4 (Belleville)	645
5 (Marion)	656
Weighted Average[435]	
ComEd	978
Ameren	800
Statewide	928

433 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).

434 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.

435 Weighting for Ameren is based on gas accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

$AFUE_{Exist}$ = 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,[436] or if unknown, assume 61.6 AFUE%.[437]

$AFUE_{Base}$ = 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:[438]

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

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[436] 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).

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

[438] 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).[439]
   - 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 in downstream programs when the actual baseline early replacement rate is unknown.[440]

Deemed Early Replacement Rates For Furnaces

Replacement Scenario for the Furnace	Deemed Early Replacement Rate
Early Replacement Rate for downstream Furnace-only participants	7%
Early Replacement Rate for a downstream furnace participant when the furnace is the Primary unit in a Combined System Replacement (CSR) project	14%
Early Replacement Rate for a downstream furnace participant 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

[439] 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.

[440] 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.

BTU measurement to ensure that newly installed equipment is operating according to manufacturers' published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Install identifies sub-optimal performance and prescribes a solution during furnace installation.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a residential sized (input energy less than 225,000 Btu/hr) natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating exceeding the program requirements.

DEFINITION OF BASELINE EQUIPMENT

Time of Sale: The current Federal Standard for gas furnaces is an AFUE rating of 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline 80% AFUE unit for the remainder of the measure life. Consistent with TRM Volume 1 Section 2.3.1 for midstream programs or other cases where the existing condition is unknown, it may be appropriate to apply a deemed percent split of Time of Sale and Early Replacement assumptions based on evaluation results

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[441]

For early replacement: Remaining life of existing equipment is assumed to be 6 years.[442]

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:[443]

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

[441] Table 8.3.3 The Technical support documents for federal residential appliance standards.

[442] Assumed to be one third of effective useful life

[443] 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.

Early Replacement: Actual install costs should be used if available. The deemed 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.[444] This cost should be discounted to present value using the nominal discount rate. For furnaces installed in mobile homes, add an extra $750 to both the full install cost and the deferred baseline cost to account for increased equipment and labor costs associated with this install.[445]

Verified Quality Installation: The additional design and installation work associated with verified quality installation has been estimated to take 1-2 hours (Tim Hanes, ESI). At $40/hr, VQI adds $60 to the installed cost.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electrical energy savings from the more fan-efficient (typically using brushless permanent magnet (BPM) blower motor) should also be claimed, please refer to “Furnace Blower Motor” characterization for details.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

If the blower motor is also used for cooling, coincident peak demand savings should also be claimed, please refer to “Furnace Blower Motor” characterization for savings details.

FOSSIL FUEL 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:[446]

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):

[444] $2641 inflated using 1.91% rate.

[445] Based on cost review and data provided by Future Energy Enterprises, 5/2022.

[446] 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).

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

Where:

CAPInput = Gas Furnace input capacity (Btuh)

= Actual. If unknown, use the table below:

Eligibility Tier	Input Capacity[447]
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[448]
1 (Rockford)	1022
2 (Chicago)	976
3 (Springfield)	836
4 (Belleville)	645
5 (Marion)	656
Weighted Average[449]	
ComEd	978
Ameren	800
Statewide	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,[450] or if unknown, assume 64.4 AFUE%.[451]

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

= 80%[452]

AFUE(eff) = Efficent Furnace Annual Fuel Utilization Efficiency Rating

= Actual. If unknown, , use the table below:

447 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.

448 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.

449 Weighting for Ameren is based on gas accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

450 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).

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

452 Code of Federal Regulations, effective November, 2015 (10 CFR 432(e)).

Eligibility Tier	AFUE (eff)[453]
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%[454]

Derating(eff) =Efficent furnace AFUE derating

=0% if verified quality installation is performed

=6.4% if verified quality installation is not performed or unknown[455]

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

453 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.

454 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.

455 Ibid

MEASURE CODE: RS-HVC-GHEF-V12-230101

REVIEW DEADLINE: 1/1/2025

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:[456]

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:

[456] 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, 11 EER, 8.2 HSPF
Central Air Conditioner	10 SEER	13 SEER
Natural Gas or LP Boiler	75% AFUE	84% AFUE
Natural Gas or LP Furnace	75% AFUE	80% AFUE
Oil Furnace	75% AFUE	83% AFUE
Oil Boiler	75% AFUE	86% AFUE
Ground Source Heat Pump	10 SEER	14 SEER, 11 EER, 8.2 HSPF

- 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

The following conversion factors are recommended for use if the efficient equipment is not rated under the new testing procedure:[457]

SEER = SEER2 / X

EER = EER2 / X

HSPF = HSPF2 / X

Where:

X	SEER	EER	HSPF
Ducted	0.95	0.95	0.91

[457] Consortium for Energy Efficiency (CEE), Testing, Testing, M1, 2, 3, Transitioning to New Federal Minimum Standards, CEE Summer Program Meeting, June 10, 2022.

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[458] 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[459]. 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.[460] 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, meeting the baselines provided below.

Unit Type	Efficiency Standard
ASHP	14 SEER, 11.8 EER, 8.2 HSPF
Natural Gas or LP Furnace	80% AFUE
Natural Gas or LP Boiler	84% AFUE
Oil Furnace	83% AFUE
Oil Boiler	86% 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).

Note: New Federal Standards affecting heat pumps become effective January 1, 2023. The new standards effective in 2023, require any residential heat pump manufactured in, or imported into, the United States to have a minimum efficiency rating meeting the following:[461]

- Split system heat pump – 14.3 SEER2 and 7.5 HSPF2
- Single-package heat pump – 13.4 SEER2 and 6.7 HSPF2

These new federal standards will be adopted by the program, beginning 1/1/2024. For the 2023 program year, the baseline equipment efficiencies are detailed in this section by replacement scenario.

458 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'.

459 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'.

460 Minimum Federal standard as of 4/16/2015.

461 The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and HSPF2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system heat pumps are 15 SEER and 8.8 HSPF and for single-package heat pumps are 14 SEER and 8 HSPF, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservations Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048 (https://www.regulations.gov/document/EERE-2014-BT-STD-0048-0200)

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[462]

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[463] and 25 years for electric resistance.[464]

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),[465] minus the assumed installation cost of the baseline equipment ($6562 + $600 per ton for ASHP[466] or $2011 for a new baseline 80% AFUE furnace, or $4053 for a new 84% AFUE boiler,[467] and $952 per ton for new baseline Central AC replacement [468]).

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 $7,527 + $688 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.[469] 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)[470]
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 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.

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462 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.
463 Assumed to be one third of effective useful life of replaced equipment.
464 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.
465 Based on data provided in 'Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives'.
466 Full install ASHP costs are based upon data provided by Ameren. See 'ASHP Costs_06242022'.
467 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.
468 Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator.
469 All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.
470 The baseline for calculating electric savings is an Air Source Heat Pump.

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%[471]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[472]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS AND FOSSIL FUEL 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 energy 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) = FuelSwitchSavings + NonFuelSwitchSavings

FuelSwitchSavings = GasHeatReplaced – GSHPSiteHeatConsumed

NonFuelSwitchSavings = FurnaceFanSavings + 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} – T_{IN}) * 1.0)) / 1,000,000)

$GSHPSiteWaterImpact_{Electric}$ = (%DHWDisplaced * (1/EF_{Elec} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0)) / 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:

[471] 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)'.

[472] 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.

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:[473]

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily	FLH_cooling (weatherized multifamily) [474]
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[475]			
ComEd	567	504	323
Ameren	810	734	470
Statewide	632	565	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 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)

473 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.

474 *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.

475 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

to account for degradation over time,[476] 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	9.7[477]	14[478]	
Ground Source Heat Pump	14[479]	14	
Central AC	9.7[480]	13[481]	
No central cooling	13 [482]	13[483]	

EER_{PL} = Part Load EER Efficiency of efficient GSHP unit[484]

= 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:[485]

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[486]	
ComEd	1,846
Ameren	1,612
Statewide	1,821

[476] 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).
[477] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[478] Minimum Federal Standard as of 1/1/2015
[479] 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.
[480] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[481] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
[482] Assumes that the decision to replace existing systems includes desire to add cooling.
[483] Assumes that the decision to replace existing systems includes desire to add cooling.
[484] 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.
[485] 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.
[486] Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

Capacity_GSHPheat = Heating Output Capacity of Ground Source Heat Pump (Btu/hr)

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

$HSPF_{base}$ =Heating Seasonal 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,[487] 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	5.78[488]	8.2	
Ground Source Heat Pump	8.2[489]	8.2	
Electric Resistance	3.41[490]		

COP_{PL} = Part Load Coefficient of Performance of efficient unit[491]

= 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%[492]

= 0% if no desuperheater installed

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

= Actual. If unknown or for new construction, assume federal standard:[493]

For <=55 gallons: 0.96 – (0.0003 * rated volume in gallons)

For >55 gallons: 2.057 – (0.00113 * rated volume in gallons)

487 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).

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

489 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.

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

491 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.

492 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.

493 Minimum Federal Standard as of 4/1/2015;.

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[494]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[495]
Multifamily - Deemed	2.1[496]
Custom	Actual Occupancy or Number of Bedrooms[497]

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 [498]

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,[499] or if unknown assume default:

Baseline/ Existing Heating System	AFUEbase		
	Early Replacement (Remaining useful life of existing equipment)[500]	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Furnace	64.4%	80%	80%
Boiler	61.6%	84%	84%

[494] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[495] 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

[496] ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

[497] 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.

[498] 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.

[499] 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).

[500] 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 (1^{st} 6 years) F_e_Exist = 3.14%[501]

For New Construction, Time of Sale and early replacement (remaining 10 years) F_e_New = 1.88%[502]

$EF_{GAS\ EXIST}$ = Energy Factor (efficiency) of existing gas water heater

= Actual. If unknown, assume federal standard:[503]

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

501 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.

502 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%.

503 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.[504] 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	7.83[505]	11[506]	
Ground Source Heat Pump	12	12	
Central AC	7.83[507]	10.5[508]	

[504] 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).

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

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

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

[508] 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[509]	10.5	

EER_{FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit [510]

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

= 72%[511]

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

= 46.6%[512]

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

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

510 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.

511 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)'.

512 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.

FOSSIL FUEL 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), 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, should therefore reflect the decrease in one fuel and increase in another, as opposed to the single savings value calculated in the "Electric and Fossil Fuel Energy Savings" section 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-V13-230101

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.[513] 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.[514]

Deemed Measure Cost

Incremental cost per installed fan is $43.50 for quiet, efficient fans.[515]

Loadshape

Loadshape R11 - Residential Ventilation

Coincidence Factor

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

513 Bi-level controls may be used by efficient fans larger than 50 CFM

514 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.

515 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[516]

$\eta_{BASELINE}$ = 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[517]

= 8766 for continuous ventilation.

Defaults provided below:[518]

Application	Min CFM	Max CFM	Average CFM	Base CFM/Watts	ENERGY STAR		ENERGY STAR Most Efficient	
					CFM/Watts	ΔkWh Savings	CFM/Watts	ΔkWh Savings
Standard usage	10	89	70.6	1.7	4.9	28.9	12.0	38.2
	90	200	116.1	2.6	5.6	25.3	13.9	38.7
	Unknown		92.4	2.2	5.3	27.4	12.9	38.6
Continuous usage	N/A		50	1.7	5.1	170.7	11.2	216.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor

= 0.135 for standard usage

= 1.0 for continuous operation

Other variables as defined above

516 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.

517 Assumed to be consistent with Residential Indoor Lighting hours of use.

518 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

FOSSIL FUEL 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.[519]

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.[520]

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%[521]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

[519] Based on DEER 2014 EUL Table for "Clean Condenser Coils – Residential" and "Refrigerant Charge – Residential".

[520] 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.

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

= 72%[522]

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

= 46.6%[523]

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:[524]

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[525]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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 [526]

MFe = Maintenance energy savings factor

[522] 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)'.

[523] 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.

[524] 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.

[525] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

[526] 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.

= 0.05[527]

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

= Actual. If unknown assume 10 SEER [528]

FLHheat = Full load heating hours

Dependent on location:[529]

Climate Zone (City based upon)	FLHheat
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[530]	
ComEd	1,846
Ameren	1,612
Statewide	1,821

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 [531]

[527] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."
[528] 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.
[529] 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.
[530] Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.
[531] 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.

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

= Calculate using Actual SEER

= $- 0.02 \cdot SEER^2 + 1.12 \cdot SEER$ [532]

MFd = Maintenance demand savings factor

= 0.02 [533]

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

= 68%[534]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[535]

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

= 46.6%[536]

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

532 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.

533 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.

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

535 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)’.

536 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.

FOSSIL FUEL SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Conservatively not included.

MEASURE CODE: RS-HVC-TUNE-V07-230101

REVIEW DEADLINE: 1/1/2025

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.[537] 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.[538] 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.[539] The cost for reprogramming

[537] 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'.
[538] 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.
[539] 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[540] = %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%[541]

Elec_Heating_ Consumption

= Estimate of annual household heating consumption for electrically heated homes.[542] If location and heating type is unknown, assume 15,683 kWh.[543]

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

540 Note the second part of the algorithm relates to furnace fan savings if the heating system is Natural Gas.
541 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"
542 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.
543 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%[544]

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

Household Type	HF
Single-Family	100%
Mobile home	83%[545]
Multifamily	65%[546]
Unknown	96.5%[547]
Actual	Custom[548]

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%[549]

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Fossil Fuel section below

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

= 3.14%[550]

29.3 = kWh per therm

544 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.

545 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.

546 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

547 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.

548 Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

549 "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness," GDS Associates, Marietta, GA. 2002GDS

550 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%[551]

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below:[552]

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

551 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"

552 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,[553] 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

[553] 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.[554]

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

[554] 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:[555]

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[556]
Air Source Heat Pump	10 SEER	14 SEER, 11 EER, 8.2 HSPF
Central Air Conditioner	10 SEER	13 SEER, 10.5 EER
Natural Gas or LP Boiler	75% AFUE	84% AFUE
Natural Gas or LP Furnace	75% AFUE	80% AFUE
Oil Furnace	75% AFUE	83% AFUE
Oil Boiler	75% AFUE	86% AFUE
Ground Source Heat Pump	10 SEER	14 SEER, 11 EER, 8.2 HSPF

- 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 in downstream programs 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%[557]

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.

The following conversion factors are recommended for use if the efficient equipment is not rated under the new

[555] 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.

[556] Based on relevant Federal Standards.

[557] Based on ComEd program data from 2018-2020 (1057 DMSHP installs).

testing procedure:[558]

SEER = SEER2 / X

EER = EER2 / X

HSPF = HSPF2 / X

Where:

X	SEER	EER	HSPF
Ductless	1.00	1.00	0.95

DEFINITION OF BASELINE EQUIPMENT

For these products, baseline equipment includes Air Conditioning and Space Heating:

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11 EER.[559]

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. [560]

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
Electric Resistance	3.412 HSPF
Natural Gas or LP Furnace	80% AFUE
Natural Gas or LP Boiler	84% AFUE
Oil Furnace	83% AFUE
Oil Boiler	86% AFUE
Central AC	13 SEER, 10.5 EER
Unknown [561]	13.28 SEER, 11.35EER, 5.53 HSPF, 81.1% AFUE

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.

Where unknown, early replacement efficiency assumptions are 9.95 SEER, 9.01 EER, 5.07 HSPF and 63% AFUE.

[558] Consortium for Energy Efficiency (CEE), Testing, Testing, M1, 2, 3, Transitioning to New Federal Minimum Standards, CEE Summer Program Meeting, June 10, 2022.

[559] 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'.

[560] 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'.

[561] Values represent the weighted average [SEER/EER/HSPF/AFUE] baseline values reflecting the assumed shares of installed DMSHP replacing given baseline technologies (e.g. ASHP/electric resistance or furnace/boiler) by fuel type. Assumed shares are based on Opinion Dynamics and Guidehouse analysis of 2018-2021 Ameren and ComEd HVAC (downstream) program tracking data. For further details, see '2018-2021 AIC Res HVAC Data ASHP Baseline TRM Update 2022-07-11.xls'.

Consistent with TRM Volume 1 Section 2.3.1 for midstream programs or other cases where the existing condition is unknown, it may be appropriate to apply a deemed percent split of Time of Sale and Early Replacement assumptions based on evaluation results

For multifamily buildings, each residence must have existing individual heating equipment. Multifamily residences with central heating do not qualify for this characterization.

Note: New Federal Standards affecting heat pumps become effective January 1, 2023. The new standards effective in 2023, require any residential heat pump manufactured in, or imported into, the United States to have a minimum efficiency rating meeting the following:[562]

- Split system heat pump – 14.3 SEER2 and 7.5 HSPF2
- Single-package heat pump – 13.4 SEER2 and 6.7 HSPF2

These new federal standards will be adopted by the program, beginning 1/1/2024. For the 2023 program year, the baseline equipment efficiencies are detailed in this section by replacement scenario.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[563]

For early replacement, the remaining life of existing equipment is assumed to be 6 years for ASHP and Central AC, 7 years for furnace and unknown, 8 years for boilers[564] and 15 years for electric resistance.[565]

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 ($6562 + $600 per ton for ASHP,[566] or $2,011 for a new baseline 80% AFUE furnace, or $4,053 for a new 84% AFUE boiler,[567] and $952 per ton for new baseline Central AC replacement [568]).

Default full cost of the DMSHP is provided below. Note, for smaller units a minimum cost of $2,000 should be applied:[569]

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562 The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and HSPF2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system heat pumps are 15 SEER and 8.8 HSPF and for single-package heat pumps are 14 SEER and 8 HSPF, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservations Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048 (https://www.regulations.gov/document/EERE-2014-BT-STD-0048-0200)

563 Based on 2016 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

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

565 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.

566 Full install ASHP costs are based upon data provided by Ameren. See 'ASHP Costs_06242022'.

567 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.

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

569 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.

Unit HSPF	Full Install Cost ($/ton)[570]
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:[571]

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 $7,527 + $688 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.[572] 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. Fuel switch scenarios are likely to require additional installation work which may include adding new electrical circuits, capping existing gas lines and upgrading electrical panels. These costs are likely to range significantly and actual values should be used wherever possible. If unknown, assume an additional $300 for fuel switch installations.

LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling (if replacing gas heat and central AC)[573]

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

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

Note for purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e., Loadshape R09 - Residential Electric Space Heat and Loadshape R08 – Residential Cooling respectively) can be applied.

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in four different ways below. The first two relate to the use of DMSHP to supplement existing cooling or provide limited zonal cooling, the second two relate to use of the

[570] 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.

[571] Memo from Opinion Dynamics Evaluation Team, Ductless Mini-Split Heat Pumps: Incremental Cost Analysis, April 27, 2017

[572] All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.

[573] The baseline for calculating electric savings is an Air Source Heat Pump.

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.[574]

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%[575]

CF_{PJM} = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

= 28.0%[576]

For Multi-Zone DMSHPs providing whole house cooling:

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%[577]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[578]

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY AND FOSSIL FUEL SAVINGS

Non fuel switch measures:

$\Delta kWh_{NonFuelSwitch}$ = [Cooling Savings] + [Heating Savings]

$= [(CoolingLoad * (1/SEER_{Base} - 1/SEER_{ee}))/1000] + [(HeatLoad * HeatLoadFactor_{elec} * (1/(HSPF_{Base} * HSPF\_ClimateAdj) - 1/(HSPF_{ee} * HSPF\_ClimateAdj)) / 1000]$

Fuel switch measures:

Fuel switch measures must produce positive total lifecycle energy 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) = FuelSwitchSavings + NonFuelSwitchSavings

FuelSwitchSavings = GasHeatReplaced – DMSHPSiteHeatConsumed

NonFuelSwitchSavings = FurnaceFanSavings + DMSHPSiteCoolingImpact

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

[575] 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)'.

[576] 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.

[577] 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)'.

[578] 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.

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

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

DMSHPSiteHeatConsumed = ((HeatLoad * $HeatLoadFactor_{elec}$ * ($1/HSPF_{ee}$ * HSPF_ClimateAdj))/1000 * 3412) / 1,000,000

DMSHPSiteCoolingImpact = ((CoolingLoad * ($1/SEER_{Base}$ - $1/SEER_{ee}$))/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.

<u>Programs where existing system unknown</u>

In programs where the existing fuel or system type is unknown, savings should be apportioned between the Fuel Switch and Non- Fuel Switch scenarios, as follows:

Savings from Non-Fuel Switch (kWh) = (1 – %FuelSwitch) * $\Delta kWh_{Non\ Fuel\ Switch}$

Plus

Savings from Fuel Switch (MMBtu converted to appropriate fuel as table above)

= %FuelSwitch * SiteEnergySavings (MMBTUs)

Where:

%FuelSwitch = The percentage of replacements resulting in fuel-switching.

= 1 when fuel switching is known

= where unknown, such as in a midstream program, determine through evaluation.

CoolingLoad = Annual cooling load being displaced

= $Capacity_{cool}$ * $EFLH_{cool}$

$Capacity_{cool}$ = the total cooling output capacity of all the ductless heat pump units installed in Btu/hr[579]

= Actual installed

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. Depends on location. See table below:[580]

Climate Zone (City based upon)	$EFLH_{cool}$
1 (Rockford)	323
2 (Chicago)	308
3 (Springfield)	468
4 (Belleville)	629
5 (Marion)	549
Weighted Average[581] ComEd Ameren Statewide	 309 496 359

$SEER_{base}$ = 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,[582] 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	9.7[583]	14[584]	
Central AC	9.7[585]	13[586]	
Room AC	8.0[587]	13	

[579] 1 Ton = 12 kBtu/hr

[580] *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.

[581] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

[582] 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).

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

[584] Minimum Federal Standard as of 1/1/2015

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

[586] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

[587] Estimated by converting the EER assumption for Room AC using the conversion equation; EER_base = (-0.02 * SEER_base²) + (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.

Baseline/Existing Cooling System	SEERbase		
	Early Replacement (Remaining useful life of existing equipment)	Early Replacement (Remaining measure life)	Time of Sale or New Construction
No central cooling	Make ‘1/SEER_exist’ = 0 [588]	13[589]	
Unknown [590]	9.95	13.28	

$SEER_{ee}$ = SEER rating of new equipment (kbtu/kwh)

= Actual installed[591]

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)	$EFLH_{heat}$[592]
1 (Rockford)	1,520
2 (Chicago)	1,421
3 (Springfield)	1,347
4 (Belleville)	977
5 (Marion)	994
Weighted Average[593]	
ComEd	1,425
Ameren	1,243
Statewide	1,374

Capacity_DMSHPheat = the total rated 47°F heating output capacity of all the ductless heat pump units installed in Btu/hr

= Actual

HeatLoadFactor = adjustment to reflect the heat load carried by the DMSHP in each use case, considering assumed operational strategy and switchover temperature, as well as DMSHP rated

[588] 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.
[589] Assumes that the decision to replace existing systems includes desire to add cooling.
[590] Values represent the weighted average SEER baseline values reflecting the assumed shares of installed DMSHP replacing given baseline technologies (e.g. ASHP/electric resistance or furnace/boiler) by fuel type. Assumed shares are based on Opinion Dynamics and Guidehouse analysis of 2018-2021 Ameren and ComEd HVAC (downstream) program tracking data. For further details, see ‘2018-2021 AIC Res HVAC Data ASHP Baseline TRM Update 2022-07-11.xls’.
[591] 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.
[592] *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.
[593] Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

capacity.[594] If new DMSHP displaces all existing heating systems, assume 1. "Partial Displacement" application refers to the condition where an existing heating system remains in place to meet heating load not provided by the heat pump.

Use factor from table below. For programs where displacement scenario and switchover temperature is unknown, evaluation should determine appropriate weightings of the various scenarios including full displacement, partial displacement and cooling/heating only.

If Partial Displacement and Simultaneous Operation[595] with existing heat type, HeatLoadFactor:

Climate Zone	≤15 kBtu	>15 and ≤21 kBtu	>21 and ≤27 kBtu	>27 and ≤33 kBtu	>33 and ≤39 kBtu	>39 and ≤45 kBtu	>45 kBtu
1 (Rockford)	2.12	1.80	1.52	1.30	1.12	0.98	0.87
2 (Chicago)	2.25	1.89	1.58	1.33	1.14	0.99	0.87
3 (Springfield)	2.01	1.68	1.40	1.18	1.00	0.87	0.77
4 (Belleville)	2.89	2.34	1.90	1.58	1.34	1.16	1.02
5 (Marion)	2.50	1.93	1.53	1.25	1.05	0.90	0.79
ComEd Weighted Average	2.03	1.72	1.46	1.24	1.07	0.94	0.83
Ameren Weighted Average	2.15	1.81	1.51	1.27	1.09	0.95	0.84
Statewide Weighted Average	2.06	1.74	1.47	1.25	1.07	0.94	0.83

If Partial Displacement and Switchover[596] at >24°F, HeatLoadFactor:

Climate Zone	≤15 kBtu	>15 and ≤21 kBtu	>21 and ≤27 kBtu	>27 and ≤33 kBtu	>33 and ≤39 kBtu	>39 and ≤45 kBtu	>45 kBtu
1 (Rockford)	0.93	0.67	0.50	0.40	0.34	0.29	0.25
2 (Chicago)	1.06	0.77	0.58	0.46	0.39	0.33	0.29
3 (Springfield)	0.92	0.66	0.49	0.39	0.33	0.28	0.25
4 (Belleville)	1.71	1.24	0.93	0.74	0.62	0.53	0.46
5 (Marion)	1.54	1.07	0.80	0.64	0.53	0.46	0.40
ComEd Weighted Average	0.89	0.64	0.48	0.39	0.32	0.28	0.24

[594] Values for HeatLoadFactor were developed by applying DMSHP capacity curves of various sizes to a modeled full home load for each of the five IL TRM climate zones. The modeled home load was developed using eQuest simulation modeling with a home size of 2,500 square feet, single-story with attic construction, and utilizing default values for shell properties, occupancy levels, etc. Thermostat setpoints were fixed to 68F without daytime or nighttime setback. To determine the home load for each climate zone, the model home was simulated using TMY3 weather files specific to the five IL TRM climate zones. The resulting hourly heating loads, 8,760 values for each climate zone, were extracted from eQuest for further analysis.

[595] The heating setpoint for the ductless heat pump is assumed to be at least 2°F higher than any remaining existing system and the cooling setpoint for the ductless heat pump is assumed be at least 2°F cooler than the existing system (this should apply to all periods of a programmable schedule, if applicable). This is necessary such that the ductless heat pump is serving as the primary unit for heating and cooling.

[596] Temperature for switching from heat pump (used for the higher temperatures) to the supplemental system (used for lower temperatures).

Ameren Weighted Average	0.99	0.72	0.54	0.43	0.36	0.31	0.27
Statewide Weighted Average	0.92	0.66	0.50	0.40	0.33	0.28	0.25

If Partial Displacement and Switchover at ≤24°F, HeatLoadFactor

Climate Zone	≤15 kBtu	>15 and ≤21 kBtu	>21 and ≤27 kBtu	>27 and ≤33 kBtu	>33 and ≤39 kBtu	>39 and ≤45 kBtu	>45 kBtu
1 (Rockford)	1.99	1.67	1.39	1.17	0.99	0.86	0.75
2 (Chicago)	2.14	1.78	1.47	1.22	1.03	0.89	0.78
3 (Springfield)	1.91	1.58	1.31	1.08	0.91	0.79	0.69
4 (Belleville)	2.79	2.24	1.80	1.48	1.25	1.07	0.94
5 (Marion)	2.47	1.90	1.50	1.22	1.02	0.88	0.77
ComEd Weighted Average	1.90	1.60	1.33	1.12	0.95	0.82	0.72
Ameren Weighted Average	2.04	1.70	1.40	1.17	0.99	0.85	0.74
Statewide Weighted Average	1.94	1.62	1.35	1.13	0.96	0.83	0.72

$HSPF_{base}$ =Heating Seasonal 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,[597] 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	5.78[598]	8.2[599]	
Electric Resistance	3.41[600]		
Unknown [601]	5.07	5.53	

HSPF_ClimateAdj = Adjustment factor to account for observed discrepency between seasonal heating performance relative to rated HSPF as provided by standard AHRI 210/240 rating conditions. Note, the adjustment is dependent on the displacement scenario and test

[597] 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).

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

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

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

[601] Values represent the weighted average HSPF baseline values reflecting the assumed shares of installed DMSHP replacing given baseline technologies (e.g. ASHP/electric resistance or furnace/boiler) by fuel type. Assumed shares are based on Opinion Dynamics and Guidehouse analysis of 2018-2021 Ameren and ComEd HVAC (downstream) program tracking data. For further details, see '2018-2021 AIC Res HVAC Data ASHP Baseline TRM Update 2022-07-11.xls'.

method use for the rating (i.e. HSPF or HSPF2 rating) [602]:

Displacement Scenario	City (county based upon)	HSPF_ClimateAdj When using HSPF rating	HSPF_ClimateAdj When using HSPF2 rating
Partial Displacement	All	100%	
Whole Heat Load Displacement	1 (Rockford)	70%	74%
	2 (Chicago)	70%	74%
	3 (Springfield)	83%	87%
	4 (Belleville)	83%	87%
	5 (Marion)	83%	87%
	Weighted Average[603]		
	ComEd	70%	74%
	Ameren	81%	85%
	Statewide	73%	77%

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,[604] or if unknown assume default:

Baseline/ Existing Heating System	AFUEbase		
	Early Replacement (Remaining useful life of existing equipment)[605]	Early Replacement (Remaining measure life)	Time of Sale or New Construction
Furnace	64.4%	80%	80%
Boiler	61.6%	84%	84%
Unknown [606]	63%	81.1%	81.1%

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

= Actual installed

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

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602 Adjustment factors are based on findings from NEEA, July 2020 'EXP07:19 Load-based and Climate-Specific Testing and Rating Procedures for Heat Pumps and Air Conditioners'. See 'NEEA HP data' for calculation. Findings were consistent with other reviewed sources including ASHRAE, 2020 'Right-Sizing Electric Heat Pump and Auxiliary Heating for Residential Heating Systems Based on Actual Performance Associated with Climate Zone' and Cadmus, 2022 'Residential ccASHP Building Electrification Study'. The difference between HSPF and HSPF2 ratings is based on the change in testing procedure that will correct for some of this effect where ducted systems will have an approximately 5% lower HSPF2 rating as compared to HSPF, based on CEE presentation, July 2022, 'Testing Testing, M1, 2, 3: Trainsitioning to New Federal Minimum Standards'.

603 Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

604 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).

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

606 Values represent the weighted average AFUE baseline values reflecting the assumed shares of installed DMSHP replacing given baseline technologies (e.g. ASHP/electric resistance or furnace/boiler) by fuel type. Assumed shares are based on Opinion Dynamics and Guidehouse analysis of 2018-2021 Ameren and ComEd HVAC (downstream) program tracking data. For further details, see '2018-2021 AIC Res HVAC Data ASHP Baseline TRM Update 2022-07-11.xls'.

= 0.44 for unknown baseline/existing heating systems[607]

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

For Early Replacement (1st 6 years) F_e_Exist = 3.14%[608]

For New Construction, Time of Sale and early replacement (remaining 10 years) F_e_New = 1.88%[609]

3412 = Btu per kWh

%IncentiveElectric = % of total incentive paid by electric utility

= Actual

%IncentiveGas = % of total incentive paid by gas utility

= Actual

607 Unknown value derived from Guidehouse DMSHP participant survey, 2022.

608 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.

609 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 partially displace electric baseboard heat with switchover at 20°F and replace a window air conditioner of unknown efficiency, savings are:

ΔkWh_{heat} = (18000 * 1421 * 1.78 * (1/3.412 – 1/8))/1000 = 7,653 kWh

ΔkWh_{cool} = (18000 * 308 *(1/8.0 – 1/14)) /1000 = 297 kWh

ΔkWh = 7,653 + 297 = 7,950 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 partially displace gas furnace heat with switchover at 28°F 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 * 0.77 * 1/0.644) / 1,000,000 * 6) + ((1421 * 18,000 * 0.77 * 1/0.8) / 1,000,000 * 9)

= 405.1 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 * 0.77 * 1/0.644 * 0.0314) / 1,000,000 * 6) + ((1 * 1421 * 18,000 * 0.77 * 1/0.8 * 0.0188) / 1,000,000 * 9)

= 9.9 MMBtu

LifetimeDMSHPSiteHeatConsumed = ((HeatLoad * (1/$HSPF_{ee}$))/1000 * 3412) / 1,000,000 * 15 years

= ((1421 * 18,000 * 0.77 * (1/9)) / 1000 * 3412)/1,000,000 * 15

= 112.0 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) = 405.1 + 9.9 – 112.0 + 7.6

= 310.6 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 * 0.77 * 1/0.644) / 1,000,000

= 30.6 MMBtu

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

= (1 * 1421 * 18,000 * 0.77 * 1/0.644 * 0.0314) / 1,000,000

= 0.9 MMBtu

DMSHPSiteHeatConsumed = ((HeatLoad * (1/$HSPF_{ee}$))/1000 * 3412) / 1,000,000

= ((1421 * 18,000 * 0.77 * (1/9)) / 1000 * 3412)/1,000,000

= 7.5 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) = 30.6 + 0.9 – 7.5 + 0.9 = 24.9 MMBtu

Remaining 9 years:

SiteEnergySavings_PostAdj (MMBTUs) = GasHeatReplaced + FurnaceFanSavings – DMSHPSiteHeatConsumed + DMSHPSiteCoolingImpact

GasHeatReplaced = (1421 * 18,000 * 0.77 * 1/0.8) / 1,000,000

= 24.6 MMBtu

FurnaceFanSavings = (1 * 1421 * 18,000 * 0.77 * 1/0.8 * 0.0188) / 1,000,000

= 0.5 MMBtu

DMSHPSiteHeatConsumed = ((1421 * 18,000 * 0.77 * (1/9)) / 1000 * 3412)/1,000,000

= 7.5 MMBtu

DMSHPSiteCoolingImpact = (((308 * 18,000 * (1/13 – 1/16))/1000 * 3412)/1,000,000

= 0.3 MMBtu

SiteEnergySavings_PostAdj (MMBTUs) = 24.6 + 0.5 – 7.5+ 0.3 = 17.9 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: 24.9 * 1,000,000/3412 = 7298 kWh Remaining 10 years: 17.9 * 1,000,000/3412 = 5246 kWh	N/A
Electric and gas utility	First 6 years: 24.9 * 0.5 * 1,000,000/3412 = 3649 kWh Remaining 10 years: 17.9 * 0.5 * 1,000,000/3412 = 2623 kWh	First 6 years: 24.9 * 0.5 * 10 = 124.5 Therms Remaining 10 years: 17.9 * 0.5 * 10 = 89.5 Therms
Gas utility only	N/A	First 6 years: 24.9 * 10 = 249 Therms Remaining 10 years: 17.9 * 10 = 179 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.[610] 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	7.83[611]	11[612]	

[610] 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).

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

[612] 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	7.83[613]	10.5[614]	
Room AC	7.7[615]	10.5	
No central cooling	Make '1/EER_exist' = 0 [616]	10.5[617]	
Unknown [618]	7.77	10.5	

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: [619]

$= (-0.02 * SEER^2) + (1.12 * SEER)$

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%[620]

CF_{PJM} = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

= 28.0%[621]

For Multi Zone DMSHPs providing whole house cooling:

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%[622]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[623]

FOSSIL FUEL SAVINGS

Calculation provided together with Electric Energy Savings above.

---

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

614 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'.

615 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."

616 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.

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

618 Program tracking data does not provide an EER value. These are estimated based on the other values in the table.

619 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.

620 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)'.

621 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.

622 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)'.

623 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), 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, should therefore reflect the decrease in one fuel and increase in another, as opposed to the single savings value calculated in the "Electric and Fossil Fuel Energy Savings" section 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 * $HeatLoadFactor_{gas}$ * 1/$AFUE_{base}$) / 100,000]

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

= [FurnaceFlag * HeatLoad * $HeatLoadFactor_{gas}$ * 1/$AFUE_{base}$ * F_e * 0.000293] - [(HeatLoad * $HeatLoadFactor_{elec}$ * 1/(HSPFee * HSPF_ClimateAd))/1000] + [($Capacity_{cool}$ * $EFLH_{cool}$ * (1/$SEER_{Base}$ - 1/$SEER_{ee}$)) / 1000]

MEASURE CODE: RS-HVC-DHP-V10-230101

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:[624]

- 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.[625]

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.

---

[624] American Standard Maintenance for Indoor Units (see 'HVAC Maintenance American Standard')

[625] 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

$\Delta kWh = \Delta Therms * F_e * 29.3$

Where:

ΔTherms = as calculated below

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

= 3.14%[626]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

FOSSIL FUEL SAVINGS

$$\Delta Therms = \frac{(CAPInputPre * EFLH * (1/\ Effbefore - 1/\ (Effbefore + Ei)))}{100{,}00}$$

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[627]
1 (Rockford)	1022
2 (Chicago)	976
3 (Springfield)	836
4 (Belleville)	645
5 (Marion)	656

[626] 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.

[627] Full load hours for Chicago, are based on findings in 'Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.

Climate Zone (City based upon)	EFLH[627]
Weighted Average[628]	
ComEd	978
Ameren	800
Statewide	928

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-V07-230101

REVIEW DEADLINE: 1/1/2025

[628] Weighting for Ameren is based on gas accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

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.[629]

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.[630]

DEEMED MEASURE COST

The cost of this measure is $612.[631]

LOADSHAPE

NA

COINCIDENCE FACTOR

N/A

---

[629] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors, See 'Boiler Reset Control – NaturalGasEfficiency.org'.

[630] 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.

[631] 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

FOSSIL FUEL SAVINGS

ΔTherms = Gas_Boiler_Load * (1/AFUE) * Savings Factor

Where:

Gas_Boiler_Load[632]

= Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below.[633]

= or Actual if informed by site-specific load calculations, ACCA Manual J, or equivalent.[634]

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%[635]

[632] 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)

[633] 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.

[634] 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.

[635] 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 91% of ceiling fans with integrated light kits leverage LED lamps; with the remaining 9% using CFLs.[636] 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.[637]

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).[638]

DEEMED MEASURE COST

Incremental cost of a ceiling fan with light kit is $46.

---

[636] 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 5/5/2022.

[637] Lifetime estimate is sourced from the ENERGY STAR Ceiling Fan Savings Calculator.

[638] 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. [639]

LOADSHAPE

R06 - Residential Indoor Lighting

R11 - Residential Ventilation

COINCIDENCE FACTOR

The summer peak coincidence factor for the ventilation savings is assumed to be 30%.[640]

For lighting savings, see 5.5.9 LED Fixtures measure.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

ΔkWh_{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:[641]

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%

---

[639] 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.

[640] 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.

[641] 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 5/5/2022. 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_2022.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 5 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 14 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 32 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	5	14	32
ΔW	10	20	35

If the lighting WattsBase and WattsEE is unknown, assume the following:[642]

WattsBase =1.2 x 46.5 = 55.8 W

WattsEE = 1.2 x 17.3 = 20.1 W

[642] Through review of the ENERGY STAR Qualified Products List, accessed on May 5, 2022, the average ceiling fan LED light kit had 1.2 lamps, with an average wattage of 17.3 W. 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*5)+(0.4*14)+(0.2*32))/1000]
>
> = 36.2 – 15.3 = 20.9 kWh
>
> ΔkWh_{light} =((88.5 – 22.4)/1000) *759 * 1.06
>
> = 53.2 kWh
>
> ΔkWh = 20.9+53.2= 74.1 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%[643]

CF_{light} = Summer Peak coincidence factor for lighting savings

= 7.1%[644]

> **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} = ((67-32)/1000) * 0.3
>
> = 0.0105 kW
>
> ΔkW_{light} =((88.5 – 22.4)/1000) * 1.11 * 0.071
>
> = 0.0052 kW
>
> ΔkW = 0.0105 + 0.0052
>
> = 0.016 kW

FOSSIL FUEL 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.

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643 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.

644 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

MEASURE CODE: RS-HVC-CFAN-V04-230101

REVIEW DEADLINE: 1/1/2026

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.[645] 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.[646] 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[647] 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,[648] or an assumed mix of these two

[645] 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.

[646] 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'.

[647] 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.

[648] 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.[649]

Deemed Lifetime of Efficient Equipment

The expected measure life for advanced thermostats is assumed to be 11 years.[650]

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,[651] or other program types, actual costs are still preferable,[652] but if unknown, then the average incremental cost for the new installation measure is assumed to be $79.[653]

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%[654]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[655]

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649 Based on Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013.

650 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.

651 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.

652 Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.

653 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 $100 and $150, excluding the availability of time or market-limited wholesale or volume pricing. Analysis of the 2021 Pricing data from AIC's Retail Products Program finds an average retail cost of $129 for Advanced Thermostats.The assumed cost for the baseline equipment (blend of manual and programmable thermostats) is $50 which leads to an incremental cost of $79 for the measure. See AIC_RetailProducts_2021Costdata_AdvThermostats_051322.xlsx for analysis of the AIC program data. 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.

654 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).

655 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[656] = $\Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating}$ = %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%[657]

Elec_Heating_Consumption

= Estimate of annual household heating consumption for electrically heated homes.[658] If location and heating type is unknown, assume 15,683 kWh.[659]

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

Heating_Reduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat including accounting for Thermostat

656 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.

657 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"

658 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.

659 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[660]

Existing Thermostat Type	Heating_Reduction[661]
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%[662]
Multifamily	65%[663]
Actual	Custom[664]
Unknown	96.5%[665]

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%[666]

[660] 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.

[661] 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.

[662] 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.

[663] 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

[664] Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

[665] 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.

[666] 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 Fossil Fuel section below

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

= 3.14%[667]

29.3 = kWh per therm

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

Thermostat control of air conditioning?	%AC[668]
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.[669]

Climate zone (city based upon)	FLH (single family) [670]	FLH (general multifamily) [671]	FLH_cooling (weatherized multifamily) [672]
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[673]			
ComEd	567	504	323
Ameren	810	734	470
Statewide	632	565	362

667 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.

668 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 ;

669 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.

670 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.

671 Ibid.

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

673 Weighted based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-3, Ameren is Zones 2-5.

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

Capacity = Size of AC unit.[674] (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.[675] If building type is unknown, assume 33,040 Btu/hr.[676]

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,[677] or:

Cooling System	SEER[678]
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:[679]

= 8.4% [680]

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674 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.

675 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.

676 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.

677 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).

678 Estimate based upon Navigant, 2018 "EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case"

679 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.

680 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

Eff_ISR_Cool = Effective In-Service Rate for cooling, the percentage of thermostats installed and configured effectively for 2-way communication. Note that retrospective adjustments should be made during evaluation verification activities through the use of a realization rate if the program design does not ensure that each advanced thermostat is actually installed and/or if the evaluation determines that the advanced thermostat is not actually installed in the Program Administrator's service territory.

Program Delivery	Eff_ISR_Cool
Direct Install	100%
Other programs where not evaluated	90%[681]

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

ΔkWH = $\Delta kWh_{heating} + \Delta kWh_{cooling}$

= 1 * 10,464 * 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%[682]

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:

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.

681 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%.

682 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.

$EER = (-0.02 * SEER\_exist^2) + (1.12 * SEER\_exist)$ [683]

If SEER or EER rating unavailable, use:

Cooling System	EER[684]
Air Source Heat Pump	10.5
Central AC	

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 34%[685]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[686]

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

FOSSIL FUEL 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%[687]

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below.[688]

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683 From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

684 Based on converting SEER assumption to EER.

685 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.)

686 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.)

687 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"

688 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

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-V08-230101

REVIEW DEADLINE: 1/1/2024

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.

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.

Optionally, when applying an early replacement rate for two-in-one boiler upgrades, the following weighted average is provided for use in downstream programs when the actual baseline early replacement rates are unknown.[689]

Deemed Early Replacement Rates for Boilers

	Deemed Early Replacement Rate
Early Replacement Rate for downstream Boiler participants	7%

This measure was developed to be applicable to the following program types: TOS or ER. 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.[690] 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 storage water heater meeting minimum Federal efficiency standards as described below:

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[691]
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 gallon tanks	Very small	UEF = 0.6470 – (0.0006 * Rated Storage Volume in Gallons)
		Low	UEF = 0.7689 – (0.0005 * Rated Storage Volume in Gallons)

689 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.

690 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".

691 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[691]
		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:[692]

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

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 50 gallon tank (resulting in 0.5633 EF).

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 21.5 years.[693]

Deemed Measure Cost

The incremental measure cost is assumed to be $1,663 for a 90-94% AFUE unit and $2,421 for a unit greater than or equal to 95% AFUE.[694]

Loadshape

N/A

Coincidence Factor

N/A

692 Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1

693 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.

694 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 assumptions.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

FOSSIL FUEL 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[695]
1 (Rockford)	1022
2 (Chicago)	976
3 (Springfield)	836
4 (Belleville)	645
5 (Marion)	656
Weighted Average[696]	
ComEd	978
Ameren	800
Statewide	928

$AFUE_{Base}$ = Baseline boiler annual fuel utilization efficiency rating

= 84%

$AFUE_{Eff}$ = Efficent boiler annual fuel utilization efficiency rating

= Actual. If unknown, use defaults dependent on tier as listed below:[697]

Measure Type	$AFUE_{Eff}$
AFUE ≥ 90%	92.5%

695 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.

696 Weighting for Ameren is based on gas accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

697 Default values per tier selected based upon the average AFUE value for the tier range except for the top tier where the minimum is used due to proximity to the maximum possible.

Measure Type	$AFUE_{Eff}$
AFUE ≥ 95%	95%

UEF_{Base} = Uniform Energy Factor rating of standard storage water heater according to federal standards provided in table in baseline section. 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)

= If tank size is unknown, assume 0.563 for a gas storage water heater with a 50-gallon storage capacity

UEF_{Eff} =Uniform Energy Factor rating for efficient combination boiler. This is assumed consistent with a condensing instantaneous gas-fired water heater.

= 0.954 [698]

GPD = Gallons per day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household [699]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[700]
Multifamily - Deemed	2.1[701]
Custom	Actual Occupancy or Number of Bedrooms[702]

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

= 50.7°F [703]

698 Average Uniform Energy Factor from CAC appliance database accessed 4/22/2022 for instantaneous gas-fired water heaters. The water heater portion of a gas high efficiency combination boiler is essentially a tankless water heater.

699 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

700 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

701 Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

702 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.

703 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 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

$\Delta Therms_{WH}$ = (1/0.5863 – 1/0.954) * (17.6 * 2.56 * 365.25 * 8.33 * (125-50.7) *1.0)/100,000

ΔTherms = 107.1 + 67.0

= 174.1 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-V04-230101

REVIEW DEADLINE: 1/1/2026

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.[704]

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.[705] 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

[704] Estimate based on assumption used in Department of Energy, Dentz et al, "Thermostatic Radiator Valve Evaluation", January 2015.
[705] 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

FOSSIL FUEL 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.[706]

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[707]

= 15% when part of a system balancing project to address overheated spaces

= 5% if installed without system balancing

[706] 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.

[707] 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.[708]

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.[709]

Loadshape

R10 Residential Electric Heating and Cooling.

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[708] State of Minnesota Technical Reference Manual, version 3, pp. 350+.
https://mn.gov/commerce/industries/energy/utilities/cip/technical-reference-manual/

[709] 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%[710]

$CF_{PJM\ SF}$ = PJM Summer Peak Coincidence Factor for ERV (average during PJM peak period)

= 95%[711]

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[712]

If ERV Brand and Model are unknown, use the appropriate values in following Table of ERV Default Values[713]:

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[714]	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

[710] Based on 24 hr /day, 7 day/w operation.

[711] Ibid.

[712] 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.

[713] 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.

[714] 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 [715, 716]

Table 1: Climate Variables - Deemed Values based on nearest city below to Customer's Site.[717]

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 [718] (Btu-hr/lb)	Daily fan use[719]
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 [720]

HVI_Rated_ASRE = HVI-Certified Adjusted Sensible Recovery Efficiency of the Brand/Model of ERV proposed to be used[721]

= 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,[722] or if not available refer to default table below:[723]

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

715 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.
716 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.
717 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.
718 Base: 28.4 BTU/lb Return Air
719 Based on defrost oversizing factor.
720 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.
721 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.
722 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).
723 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)[724]	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[725], 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%

[724] 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.

[725] 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[726]

= 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[727] 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

[726] 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".

[727] 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,[728] or if unknown assume the following:[729]

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[730].

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)[731]	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:

728 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).

729 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.

730 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.

731 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[732]

= 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[733]

= 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.

[732] 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.

[733] 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.[734]

$CF_{SSP\ SF}$ = Summer System Peak Coincidence Factor for ERV (during utility peak hour)

= 95%[735]

$CF_{PJM\ SF}$ = PJM Summer Peak Coincidence Factor for ERV (average during PJM peak period)

= 95%[736]

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

FOSSIL FUEL 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

734 Deemed continual operation of ERV throughout year.

735 Based on 24 hr /day, 7 day/w operation.

736 Ibid.

HVI_Max_CFM = HVI-Certified Maximum CFM of the Brand/Model of ERV proposed to be used[737]

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[738]

HVI_Rated_ASRE = HVI-Certified Adjusted Sensible Recovery Efficiency of the Brand/Model of ERV proposed to be used[739]

= 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).[740] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[741] 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[742], 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%**

737 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.
738 Used to convert Annual HDD (F-Days) to total deltaT-hours (F-Hr) per year.
739 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.
740 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.
741 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).
742 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

5.3.21 Air Handler Filter Cleaning/Replacement

Description

A dirty air handler filter increases electricity consumption for circulating fans and decreases system heating and cooling efficiencies. This measure characterizes a direct install style program whereby an existing dirty filter is either cleaned or replaced. This measure applies to central forced-air furnaces, central AC and heat pump systems. Where homes do not have central cooling, only the annual heating savings will apply.

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

Definition of Efficient Equipment

The efficient condition is a cleaned or replaced air handler filter.

Definition of Baseline Equipment

The baseline condition is an air handler filter with dirt build up and result in a blower fan motor working harder and the heating/cooling system efficiency degrading.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 3 years[743].

Deemed Measure Cost

The actual measure cost to clean or replace the filter should be used. If costs are unavailable assume $30 for a filter clean (assuming ½ hour at $60 an hour) or $50 for a new filter ($20 for the filter plus ½ hour at $60 an hour).

Loadshape

Loadshape R10 - Residential Electric Heating and Cooling

Loadshape R09 - Residential Electric Space Heat

Coincidence Factor

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

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 68%[744]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 46.6%[745]

743 Consistent with furnace tune-up measure.

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

745 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 ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kW_{motor} * (EFLH_{heat} + (\%AC * EFLH_{cool})) * \%FanSave$$

Where:

kW_{motor} = Average air handler fan motor full load electric demand

= 0.377 kW[746]

$EFLH_{heat}$ = Equivalent Full Load Hours for heating. Depends on location. See table below

Climate Zone (City based upon)	$EFLH_{heat}$[747]
1 (Rockford)	1,520
2 (Chicago)	1,421
3 (Springfield)	1,347
4 (Belleville)	977
5 (Marion)	994
Weighted Average	1,406

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

Thermostat control of air conditioning?	%AC[748]
Yes	100%
No	0%
Unknown	82.5%

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. Depends on location. If no cooling, assume 0. See table below[749].

Climate Zone (City based upon)	$EFLH_{cool}$
1 (Rockford)	323

[746] Typical blower motor capacity for gas furnace is ¼ to ¾ HP. Midpoint is ½ HP. ½ HP × 0.746 (kW/hp)=0.377kW.

[747] *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.

[748] 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 ;

[749] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. FLH values are based on metering of Multifamily units, and in buildings that had received weatherization improvements. Additional evaluation is recommended to refine the EFLH assumptions for the general population.

Climate Zone (City based upon)	$EFLH_{cool}$
2 (Chicago)	308
3 (Springfield)	468
4 (Belleville)	629
5 (Marion)	549
Weighted Average[750]	364

%FanSave = Assumed percent fan savings

= 10%[751]

For example, replacing an air handler filter in a home with a gas furnace and central cooling in Chicago:

ΔkWh = 0.377 * (1,421 + (1 * 308)) * 0.1

= 65.2 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = kW_{motor} * \%AC * \%FanSave * CF$

Where:

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

= 68%[752]

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

= 46.6%[753]

For example, replacing an air handler filter in a home with a gas furnace and central cooling in Chicago:

ΔkW_{SSP} = 0.377 * 1 * 0.1 * 0.68

= 0.0256 kW

NATURAL GAS SAVINGS

ΔTherms = %FossilHeat * Gas_Heating_Consumption * EI

Where:

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

Heating fuel	%FossilHeat
Electric	0%

750 Weighted based on number of residential occupied housing units in each zone.
751 Based on Energy.gov website; "Maintaining Your Air Conditioner". Accessed 7/16/2014, which states that replacing a dirty air filter with a clean one can lower total air conditioner energy consumption by 5-15%. Since most savings will be to the fan motor, assuming 10%.
752 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
753 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.

Heating fuel	%FossilHeat
Natural Gas	100%
Unknown	97%[754]

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below[755].

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

EI = Estimated savings from efficiency Improvement

= 1%[756]

For example, replacing an air handler filter in a home with a gas furnace and central cooling in Chicago:

ΔTherms = 1.0 * 1005 * 0.01

= 10.1therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-AHFR-V01-230101

REVIEW DEADLINE: 1/1/2025

754 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"

755 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.

756 Based on Michael Blasnik estimate of 1% gas savings for 25% air flow change; final slide of presentation: https://buildingscience.com/sites/default/files/01_Lies_Damned_Lies_and_Modeling_rev.pdf

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.[757]

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.[758] For foam pipe insulation assume a measure cost of $0.26/ft for ½" insulation and $0.31/ft for ¾" insulation.[759]

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

$$\Delta kWh = \%Electric\_DHW * ((1 / R_{exist} - 1 / R_{new}) * C_{inside} * L_{effective} * \Delta T * 8{,}766 * ISR) / \eta DHW / 3412$$

[757] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[758] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
[759] Review of website cost data for Homedepot.com, Lowes.com, and Menards.com for locations in Peoria, IL.

Where:

%Electric_DHW = Percentage of DHW savings assumed to be electric

= 100 % for Electric

= 0 % for Fossil Fuel

= If unknown[760], use the following table:

Utility	Location: Single Family	Location: Single Family Low Income	Location: Multi Family	Location: Multi Family Low Income	Location: Unknown
Ameren[761]	24%	25%	40%	43%	28%
ComEd[762]	8%		11%		9%
People's Gas[763]	23%	26%	49%	50%	63%
Northshore Gas[764]	20%				
Nicor Gas[765]	20%				
All DUs					28%

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[766])

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) [767]

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

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

---

760 Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

761 Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

762 Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

763 Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

764 Ibid.

765 Comparable service area & customers to NSG, therefore using their survey data.

766 Where possible it should be ensured that the R-value of the insulation is at the appropriate mean rating temperature (100F).

767 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.

horizontal.

ΔT = Average temperature difference between supplied water and outside air temperature (°F)

= 60°F [768]

8,766 = Hours per year

ISR = In Service Rate

= 0.50 for Kits distribution[769], 0.78 for Virtual Assessment followed by Self-Installation[770], and 1.0 for Direct Install, TOS, or Verified Install program types

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [771]

3412 = Conversion from Btu to kWh

Parameter assumptions for various pipe sizes and materials:

Type and Size	C_{Inside}[772] (I.D.*π/12) (ft)	Product of Overall Heat Transfer Coefficient and Pipe Area (UA) per foot[773] from bare pipe (BTU/hr·ft·°F)	Pipe Area per linear foot (ft^3)[774]	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:

$$\Delta kWh = (((1 / R_{exist} - 1 / R_{new}) * C_{inside} * L_{effective} * \Delta T * 8{,}766 * 1.0) / \eta DHW) / 3412$$

$$= (((1/0.521 - 1/3.521) * 0.2055 * (2 + 4 * 0.72) * 60 * 8766 * 1.0) / 0.98)/3412$$

$$= 258 \text{ kWh}$$

The following table provides annual energy savings per foot of pipe insulation for various configurations:

768 Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

769 Average of 2020 survey research by Guidehouse, conducted with Peoples Gas income qualified recipients of self install efficiency kits distributed by mail in late 2019 (with 117 survey respondents) and research from 2021 Ameren Illinois Income Qualified participant survey, available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf

770 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.

771 Electric water heaters have recovery efficiency of 98%.

772 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.

773 Laboratory measured values from Hoeschele and Weitzel (2012), Figure 1.

774 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 = 50%)**	**All Other Programs (ISR = 100%)**
Horizontal Pipe Orientation		
½” Copper Pipe insulated with R-3, ½” thick insulation	22	44.0
¾” Copper Pipe insulated with R-3, ½” thick insulation	26.5	52.9
½” PEX insulated with R-3, ½” thick insulation	27.1	54.2
¾” PEX insulated with R-3, ½” thick insulation	33.4	66.7
Vertical Pipe Orientation		
½” Copper Pipe insulated with R-3, ½” thick insulation	14.8	29.5
¾” Copper Pipe insulated with R-3, ½” thick insulation	19.1	38.1
½” PEX insulated with R-3, ½” thick insulation	19.8	39.5
¾” PEX insulated with R-3, ½” thick insulation	25.7	51.3
Unknown		
R-3, ½” thick insulation for ½” pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	20.9	41.8
R-3, ½” thick insulation for ¾” pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	26.1	52.2
Unknown pipe type (straight average) and configuration (assume 3 ft vertical and remaining horizontal) insulated with R-3, ½” thick insulation	23.5	46.9

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 = 50%)	All Other Programs (ISR = 100%)
Horizontal Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	0.0025	0.0050
¾" Copper Pipe insulated with R-3, ½" thick insulation	0.0030	0.0060
½" PEX insulated with R-3, ½" thick insulation	0.0031	0.0062
¾" PEX insulated with R-3, ½" thick insulation	0.0038	0.0076
Vertical Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	0.0017	0.0034
¾" Copper Pipe insulated with R-3, ½" thick insulation	0.0022	0.0043
½" PEX insulated with R-3, ½" thick insulation	0.0023	0.0045
¾" PEX insulated with R-3, ½" thick insulation	0.0030	0.0059
Unknown		
R-3, ½" thick insulation for ½" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.0024	0.0048
R-3, ½" thick insulation for ¾" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.0030	0.0060
Unknown pipe type (straight average) and configuration (assume 3 ft vertical and remaining horizontal) insulated with R-3, ½" thick insulation	0.0027	0.0053

NATURAL GAS SAVINGS

For Natural Gas DHW systems:

ΔTherm = %Fossil_DHW * (((1 / R_{exist} – 1 / R_{new}) * C_{inside} * $L_{effective}$ * ΔT * 8,766 * ISR) / ηDHW) /100,000

Where:

%Fossil_DHW = Percentage of DHW savings assumed to be fossil fuel

= 100 % for Fossil Fuel

= 0 % for Electric

= If unknown[775], use the following table:

[775] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

	Location				
Utility	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[776]	76%	75%	60%	57%	72%
ComEd[777]	92%		89%		91%
People's Gas[778]	77%	74%	51%	50%	37%
Northshore Gas[779]	80%				
Nicor Gas[780]	80%				
All DUs					**72%**

ηDHW = Recovery efficiency of fossil hot water heater

= 0.78 [781]

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:
>
> ΔTherm = $(((1 / R_{exist} - 1 / R_{new}) * C_{inside} * L_{effective} * \Delta T * 8{,}766 * ISR) / \eta DHW) / 100{,}000$
>
> = (((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 = 50%)	All Other Programs (ISR = 100%)
Horizontal Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	0.95	1.89
¾" Copper Pipe insulated with R-3, ½" thick insulation	1.14	2.27
½" PEX insulated with R-3, ½" thick insulation	1.16	2.32
¾" PEX insulated with R-3, ½" thick insulation	1.43	2.86
Vertical Pipe Orientation		
½" Copper Pipe insulated with R-3, ½" thick insulation	0.63	1.26

[776] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

[777] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

[778] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

[779] Ibid.

[780] Comparable service area & customers to NSG, therefore using their survey data.

[781] 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%

Measure Configuration	ΔTherm Savings per Foot of Insulation (Therms/ft)	
	Kit Distribution (ISR = 50%)	All Other Programs (ISR = 100%)
¾” Copper Pipe insulated with R-3, ½” thick insulation	0.82	1.63
½” PEX insulated with R-3, ½” thick insulation	0.85	1.70
¾” PEX insulated with R-3, ½” thick insulation	1.1	2.20
Unknown		
R-3, ½” thick insulation for ½” pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.9	1.79
R-3, ½” thick insulation for ¾” pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	1.12	2.24
Unknown pipe type (straight average) and configuration (assume 3 ft vertical and remaining horizontal) insulated with R-3, ½” thick insulation	1.01	2.01

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-PINS-V06-230101

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. [782]

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[783]
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)

[782] 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

[783] 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[783]
	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:[784]

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.[785]

For early replacement: Remaining life of existing equipment is assumed to be 4 years.[786]

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.[787]

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.[788] 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

784 Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1

785 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.

786 Assumed to be one third of effective useful life

787 Source for cost info; DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14.

788 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

FOSSIL FUEL 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:[789]

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[790] 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)

[789] 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).

[790] 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[791] 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 [792]

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household.[793]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[794]
Multifamily - Deemed	2.1[795]
Custom	Actual Occupancy or Number of Bedrooms[796]

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 [797]

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791 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

792 Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.

793 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

794 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

795 Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

796 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.

797 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

A heat pump water heater provides domestic water heating by moving heat between indoor air (conditioned or unconditioned) and a storage water tank.

This measure characterizes:

a) New Construction:
- The installation of a domestic heat pump water heater meeting ENERGY STAR efficiency standards in a new home.
- Note that 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 domestic heat pump water heater in place of a standard electric or fossil fuel-fired water heater in a home.
- Note that the baseline in this case is an equivalent replacement system to that which exists currently in the home. Where unknown, the baseline can be assumed to be a 50 gallon electric storage water heater with medium draw pattern.

c) Early Replacement
- The early removal of a functioning fossil-fuel fired water heater from service, prior to its natural end of life, and replacement with a new domestic heat pump water heater.
- Note that the baseline in this case is the existing equipment being replaced. Savings are calculated between the existing unit and efficient unit consumption during the remaining life of the existing unit, and between a new equivalent replacement system to that which exists currently in the home and efficient unit consumption for the remainder of the measure life.

Savings are presented dependent on the heating system installed in the home, presence of cooling, and presence of dehumidification due to the impact of the heat pump water heater on the heating cooling and dehumidification loads.

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

DEFINITION OF BASELINE EQUIPMENT

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

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[798]
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	Very small	UEF = 1.9236 – (0.0011 * Rated Storage Volume in Gallons)
		Low	UEF = 2.0440 – (0.0011 * Rated Storage Volume in Gallons)

[798] 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.

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[798]
	gallon tanks [799]	Medium	UEF = 2.1171 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 2.2418 – (0.0011 * Rated Storage Volume in Gallons)
Residential Electric Instantaneous Water Heaters	≤12kW and ≤2 gal	All other	UEF = 0.91
		High	UEF = 0.92
Residential 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 gallon tanks	Very small	UEF = 0.6470 – (0.0006 * Rated Storage Volume in Gallons)
		Low	UEF = 0.7689 – (0.0005 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.7897 – (0.0004 * Rated Storage Volume in Gallons)
		High	UEF = 0.8072 – (0.0003 * Rated Storage Volume in Gallons)
Residential Oil Storage Water Heater	≤50 gallon tanks	Very small	UEF = 0.2509 − (0.0012 * Rated Storage Volume in Gallons)
		Low	UEF = 0.5330 − (0.0016 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.6087 − (0.0016 * Rated Storage Volume in Gallons)
		High	UEF = 0.6815 − (0.0014 * Rated Storage Volume in Gallons)

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;[800] i.e., 0.9299 UEF assuming high draw .

If unknown, assume a 50 gallon resistance tank baseline, at medium draw, therefore 0.9207 UEF. [801]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[802]

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.[803] 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.[804] 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).

[799] It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline.

[800] 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.

[801] About 90% of all water heaters are installed in a replace-on-burnout situation and installers strongly prefer like-for-like equipment replacements in these situations, meaning that fuel switching is unlikely in TOS situations. As stated in Opinion Dynamics Ameren Illinois' Market Effects Pilot – Heat Pump Hot Water Market Characterization Report, March 4, 2021.

[802] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[803] 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.

[804] Costs for <2.6 UEF are based upon averages from the NEEP Phase 3 Incremental Cost Study. The assumption for higher efficiency tanks is based upon averaged from NEEP Phase 4 Incremental Cost Study. See 'HPWH Cost Estimation.xls' for more information.

Capacity	Efficiency Range	Baseline Installed Cost	Efficient Installed Cost	Incremental Installed Cost
≤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%.[805]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY AND FOSSIL FUEL SAVINGS

Non fuel switch measures:

ΔkWh = $(((1/UEF_{BASE} - 1/UEF_{HPWHEFFICIENT}) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) + CoolingImpact - ElecHeatImpact + Deh\_Reduction$

CoolingImpact[806] = Cooling savings from conversion of heat in home to water heat

$=((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) - ((1/ UEF_{HPWHEFFICIENT} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 27\%) / COP_{COOL}) * LM$

ElecHeatImpact = Electric heating cost from conversion of heat in home to water heat (dependent on heating fuel)

$= (((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) - ((1/ UEF_{HPWHEFFICIENT} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 5\%) / COP_{HEAT}) * (1 - \%NaturalGas)$

Deh_Reduction = Savings resulting from reduced dehumidification (provided in table in variable list below)

$\Delta Therms_{HeatImpact}$ = Fossil heating cost from conversion of heat in home to water heat for homes with Natural Gas heat

$= - (((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) - (GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) / UEF_{HPWHEFFICIENT})) * LF * 5\% * 0.03412) / \eta Heat) * \%Fossil$

805 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

806 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.

Fuel switch measures:

Fuel switch measures must produce positive total lifecycle energy savings (i.e., reduction in Btus at the premises) in order to qualify. This is determined as follows:

SiteEnergySavings (MMBTUs) = [FossilWHReplaced] – [ElectricWHAdded] + [HVACImpacts]

FossilWHReplaced = Fossil fuel consumption of replaced fossil fuel water heater

$= (1/UEF_{GASBASE} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0)/1{,}000{,}000$

ElectricWHAdded = Added electric consumption of heat pump water heater

$= (1/ UEF_{HPWHEFFICIENT} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) /1{,}000{,}000$

HVACImpacts = Heating and cooling impact of heat pump water heater

$= [CoolingImpact * 3{,}412/1{,}000{,}000] – [ElecHeatImpact * 3{,}412/1{,}000{,}000] + [Deh\_reduction * 3{,}412/1{,}000{,}000] – [\Delta Therms_{HeatImpact} * 1/10]$

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 terms of the existing water heater should be used for the remaining useful life of the existing equipment and the efficiency terms for a new baseline unit should be used for the remaining years of the measure. See assumptions below.

Where:

UEF_{BASE} = Uniform Energy Factor (efficiency) of standard 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 assume electric water heater:

For <=55 gallons: 0.9307 – (0.0002 * rated volume in gallons)

For >55 gallons: Use 0.9299 [807]

[807] 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 [808]

$UEF_{HPWHEFFICIENT}$ = 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 [809]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[810]
Multifamily - Deemed	2.1[811]
Custom	Actual Occupancy or Number of Bedrooms[812]

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 [813]

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

3412 = Conversion from Btu to kWh

CoolingImpact[814] = Cooling savings from conversion of heat in home to water heat

$$=(((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) - ((1/ UEF_{HPWHEFFICIENT} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 27\%) / COP_{COOL}) * LM$$

Where:

[808] Assuming a 50 gallon tank baseline at Medium Draw.

[809] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[810] 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

[811] Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

[812] 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.

[813] 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.

[814] 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[815]

= 0.0 for installation in an unconditioned space

27% = Portion of reduced waste heat that results in cooling savings[816]

COP_{COOL} = COP of central air conditioning

= Assume 3.3 if central AC or unknown and 3.4 if heat pump [817]

LM = Latent multiplier to account for latent cooling demand

= 1.33 [818]

ElecHeatImpact = Heating cost from conversion of heat in home to water heat (dependent on heating fuel)

= (((((GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) –

((1/ $UEF_{HPWHEFFICIENT}$* GPD * Household * 365.25 * γWater * (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[819]

COP_{HEAT} = COP of electric heating system

= actual. If not available use:[820]

System Type	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.412)*0.85
Heat Pump	8.2	2.0
Resistance	N/A	1.00
Unknown	N/A	1.35

815 West Hills Energy and Computing (2019) found 78% of HPWHs “are installed in basements that are not intentionally heated.”
816 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).
817 To reduce complexity of the measure and since this relates to a small waste heat impact, instead of assuming actual existing unit HVAC efficiency and a mid-life adjustment to account for future replacement efficiency, the code minimum baseline should be applied. Starting from federal baseline of SEER 13 central AC unit, converted to 11.1 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 = 3.3COP. Same calculation starting with federal baseline of SEER 14 heat pump results in COP of 3.4.
818 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.
819 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: 22.6×10^5 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.
820 To reduce complexity of the measure and since this relates to a small waste heat impact, instead of assuming actual existing unit HVAC efficiency and a mid-life adjustment to account for future replacement efficiency, the code minimum baseline should be applied. Note efficiency includes duct losses. Defaults provided assume 15% duct loss for heat pumps.

System Type	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.412)*0.85
electric[821]		

Deh_Reduction = Savings resulting from reduced dehumidification

= values based on table below[822]

Dehumidifcation Status	Deh_Reduction (kWh)
If Dehumidifer is in use	359
If unknown	72

$\Delta Therms_{HeatImpact}$ = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat [823]

0.03412 = conversion factor (therms per kWh)

ηHeat = Efficiency of heating system

= Assume 68% for gas furnace or unknown, 71% for oil furnace, 84% for gas boiler and 86% for oil boiler. [824]

%NaturalGas = Factor dependent on heating fuel:

= 100 % for Natural Gas

= 0 % for Electric Resistance or Heat Pump

= If unknown[825], 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%

821 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.

822 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.

823 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.

824 To reduce complexity of the measure and since this relates to a small waste heat impact, instead of assuming actual existing unit HVAC efficiency and a mid-life adjustment to account for future replacement efficiency, the code minimum baseline should be applied. Note efficiency includes duct losses. Defaults provided assume 15% duct loss for heat pumps.

825 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	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
PGL	84%	78%	60%	50%	69%
NSG	92%	84%	65%	59%	80%
Nicor	92%	84%	65%	59%	80%
All DUs					**76%**

For example, a 2.0 UEF heat pump water heater, in a conditioned space in a single family home with gas furnace space heat (68% system efficiency) 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

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) / 0.68) * 1

= - 3.7 therms

Fuel Switch example, a 2.0 UEF heat pump water heater, in a conditioned space in a single family home with gas furnace space heat (68% system efficiency) and central air conditioning (SEER 10.5) in in Belleville and dehumidifier usage is unknown, in place of a baseline 0.64UEF gas water heater:

SiteEnergySavings (MMBTUs) = [FossilWHReplaced] – [ElectricWHAdded] + [HVACImpacts]

FossilWHReplaced = (1/$UEF_{GASBASE}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0)/1,000,000

= (1/0.64 * 17.6 * 2.56 * 365.25* 8.33 * (125 – 50.7) * 1.0)/1,000,000

= 15.9 MMBtu

ElectricWHAdded = (1/ $UEF_{HPWHEFFICIENT}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) /1,000,000

= (1/2.0 * 17.6 * 2.56 * 365.25* 8.33 * (125 – 50.7) * 1.0)/1,000,000

= 5.1 MMBtu

HVACImpacts = [CoolingImpact * 3,412/1,000,000] – [ElecHeatImpact * 3,412/1,000,000] + [Deh_reduction * 3,412/1,000,000] – [$\Delta Therms_{HeatImpact}$ * 1/10]

= (188.9 * 3412/1000000) – (0 * 3412/1000000) + (72 * 3412/1000000) – (3.7 * 1/10)

= 0.5 MMBtu

SiteEnergySavings (MMBTUs) = 15.9 – 5.1 + 0.5

= 11.3 MMBtu

If supported by an electric utility: ΔkWh = ΔSiteEnergySavings * 1,000,000 / 3,412

= 11.3 * 1,000,000/3,412

= 3312 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / Hours * CF

Where:

Hours = Full load hours of water heater

= 2533 [826]

CF = Summer Peak Coincidence Factor for measure

= 0.12 [827]

[826] Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

[827] Calculated from Figure 8 "Combined six-unit summer weekday average electrical demand" in FEMP study; 'Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters' as (average kW usage during peak period * hours in peak period) / [(annual kWh savings / FLH) * hours in peak period] = (0.1 kW * 5 hours) / [(2100 kWh / 2533 hours) * 5 hours] = 0.12

For example, a 2.0 UEF heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning in Belleville and dehumidifier usage is unknown:

kW = 2010 / 2533 * 0.12

= 0.095kW

FOSSIL FUEL 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 fossil fuel to electric.

For the purposes of forecasting load reductions due to fuel switch projects per Section 16-111.5B, changes in site energy use at the customer's meter (using ΔkWh algorithm below), 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, should therefore reflect the decrease in one fuel and increase in another, as opposed to the single savings value calculated in the "Electric and Fossil Fuel Energy Savings" section above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Gas Water Heating Consumption Replaced] – [$\Delta Therms_{HeatImpact}$]

= [(1/$UEF_{GASBASE}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0)/100,000] – [((((GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) – (GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) / $UEF_{HPWHEFFICIENT}$)) * LF * 5% * 0.03412) / ηHeat) * %Fossil]

ΔkWh = - [Electric Water Heating Consumption Added] + [CoolingImpact] – [ElecHeatImpact] + [Deh-Reduction]

= - (1/ $UEF_{HPWHEFFICIENT}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) /3,412] + [((((GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) – ((1/ $UEF_{HPWHEFFICIENT}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)) * LF * 27%) / COP_{COOL}) * LM] – [((((GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) – ((1/ $UEF_{HPWHEFFICIENT}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)) * LF * 5%) / COP_{HEAT}) * (1 - %NaturalGas)] + [Deh-Reduction]

MEASURE CODE: RS-HWE-HPWH-V12-230101

REVIEW DEADLINE: 1/1/2027

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.[828]

DEEMED MEASURE COST

For time of sale or new construction the incremental cost for this measure is $3,[829] 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[830] 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%.[831]

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828 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
829 2011, Market research average of $3.
830 Includes assess and install labor time of $5 (20min @ $15/hr)
831 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[832] (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 = Percentage of DHW savings assumed to be electric

= 100 % for Electric

= 0 % for Fossil Fuel

= If unknown[833], use the following table:

	Location				
Utility	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[834]	24%	25%	40%	43%	28%
ComEd[835]	8%		11%		9%
People's Gas[836]	23%	26%	49%	50%	63%
Northshore Gas[837]	20%				
Nicor Gas[838]	20%				
All DUs					28%

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,[839] or if measured during DI:

[832] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.

[833] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

[834] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

[835] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

[836] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

[837] Ibid.

[838] Comparable service area & customers to NSG, therefore using their survey data.

[839] 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.

= Measured full throttle flow * 0.83 throttling factor[840]

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[841]
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"

= 0.94,[842] or custom based on metering studies,[843] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[844]

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[845]
Bathroom	1.6[846]
If faucet location unknown (total for household): Single-Family except mobile homes	9.0[847]
If location unknown (total for household): Multifamily and mobile homes	6.9[848]
If faucet location and building type unknown (total for household)	8.3[849]

840 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

841 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.

842 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.

843 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.

844 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.

845 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.

846 Ibid.

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

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

849 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.

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[850]
Bathroom	1.6[851]
If faucet location unknown (total for household): Single-Family except mobile homes	9.0[852]
If faucet location unknown (total for household): Multifamily	6.9[853]
If faucet location and building type unknown (total for household)	8.3[854]

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[855]
Multi-Family - Deemed	2.1[856]
Household type unknown	2.42[857]
Custom	Actual Occupancy or Number of Bedrooms[858]

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[859]
Kitchen	75%
Bath	90%
Unknown	79.5%

[850] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[851] Ibid.

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

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

[854] 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.

[855] 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

[856] Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

[857] 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.

[858] 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.

[859] 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.

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[860]
Bathroom Faucets Per Home (BFPH): Multifamily and mobile homes	1.5[861]
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
If faucet location and building type unknown (total for household)	3.42[862]

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[863]

SupplyTemp = Assumed temperature of water entering house

= 50.7°F [864]

RE_electric = Recovery efficiency of electric water heater

= 98% [865]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below

[860]Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
[861] Ibid.
[862] 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.
[863] 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.
[864] 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.
[865] Electric water heaters have recovery efficiency of 98%.**Error! Hyperlink reference not valid.**

Selection	ISR
Direct Install	0.93[866,867]
Virtual Assessment followed by Unverified Self-Install	0.77[868,869]
Requested Efficiency Kit	0.60[870]
Distributed Efficiency Kit (Income Eligible)	0.46[871]
Community Distributed Kit	0.45[872]
Distributed School Efficiency Kit	0.27[873]

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

ΔkWh = 1.0 * (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.1054 * 0.93

= 213.4 kWh

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

ΔkWh = 1.0 * (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.0879 * 0.93

= 35.5 kWh

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

ΔkWh = 1.0 * (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.1004 * 0.93

= 104.4 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[874]

[866] 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.

[867] Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report DRAFT 2013-01-28

[868] 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.

[869] 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.

[870] 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.

[871] Average of Guidehouse survey research for Peoples Gas, June 16, 2020 and Research from 2021 Ameren Illinois Income Qualified participant survey, available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf

[872] Research from 2018 Ameren Illinois Income Qualified participant survey.

[873] Opinion Dynamics and Cadmus. 2018 AIC Residential Program Annual Impact Evaluation Report. April 30, 2019. Results from implementer-administered participant survey.

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

For example, a direct installed kitchen low flow aerator in an single family home

ΔWater (gallons) = (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.93

= 2025 gallons

ΔkWh_{water} = 2025/1000000 * 5010

=10.1 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 faucet use per faucet

= ((GPM_base * L_base) * Household/FPH * 365.25 * DF) * 0.567[875] / 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
	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[876]

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

ΔkW =178/112 * 0.022

= 0.035 kW

FOSSIL FUEL SAVINGS

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_gas * ISR

Where:

[875] 56.7% is the proportion of hot 120F water mixed with 50.7F supply water to give 90F mixed faucet water.

[876] Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% *180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022

%FossilDHW = Percentage of DHW savings assumed to be fossil fuel

= 100 % for Fossil Fuel

= 0 % for Electric

= If unknown[877], use the following table:

	Location				
Utility	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[878]	76%	75%	60%	57%	72%
ComEd[879]	92%		89%		91%
People's Gas[880]	77%	74%	51%	50%	37%
Northshore Gas[881]	80%				
Nicor Gas[882]	80%				
All DUs					**72%**

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[883]

= 67% For shared water heater[884]

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.

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877 Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

878 Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

879 Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

880 Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

881 Ibid.

882 Comparable service area & customers to NSG, therefore using their survey data.

883 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%.

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

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

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 * 0.93

= 9.11 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 * 0.93

= 1.78 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 * 0.93

= 4.47 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) * 0.93

= 2025 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) * 0.93

= 404 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) * 0.93

= 1040 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES

Source ID	Reference
1	2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011.
2	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
3	1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999.
4	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
5	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
6	2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011.
7	2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.

MEASURE CODE: RS-HWE-LFFA-V12-230101

REVIEW DEADLINE: 1/1/2025

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.[885]

Deemed Measure Cost

For time of sale or new construction the incremental cost for this measure is $7 or program actual.[886]

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[887] 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%.[888]

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[885] 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.
[886] Market research average of $7.
[887] Includes assess and install labor time of $5 (20min @ $15/hr)
[888] 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 = Percentage of DHW savings assumed to be electric

= 100 % for Electric

= 0 % for Fossil Fuel

= If unknown[889], use the following table:

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[890]	24%	25%	40%	43%	28%
ComEd[891]	8%		11%		9%
People's Gas[892]	23%	26%	49%	50%	63%
Northshore Gas[893]	20%				
Nicor Gas[894]	20%				
All DUs					28%

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.

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

[889] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

[890] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

[891] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

[892] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

[893] Ibid.

[894] Comparable service area & customers to NSG, therefore using their survey data.

Program	GPM_base
Direct-install	2.24[895]
Retrofit, Efficiency Kits, NC or TOS	2.35[896]

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[897]

L_base = Shower length in minutes with baseline showerhead

= 7.8 min[898]

L_low = Shower length in minutes with low-flow showerhead

= 7.8 min[899]

Household = Average number of people per household

Household Unit Type[900]	Household
Single-Family - Deemed	2.56[901]
Multi-Family - Deemed	2.1[902]
Household type unknown	2.42[903]
Custom	Actual Occupancy or Number of Bedrooms[904]

Use Multifamily if: Building meets utility's definition for multifamily

895 Based on measurements conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

896 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.

897 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.

898 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.

899 Ibid.

900 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

901 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

902 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

903 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.

904 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

SPCD = Showers Per Capita Per Day

= 0.6[905]

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[906]
Multifamily and mobile homes	1.3[907]
Household type unknown	1.64[908]
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

= 101°F[909]

SupplyTemp = Assumed temperature of water entering house

= 50.7°F [910]

RE_electric = Recovery efficiency of electric water heater

= 98%[911]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead dependant on install method as listed in table below

905 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

906 Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

907 Ibid.

908 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.

909 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

910 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.

911 Electric water heaters have recovery efficiency of 98%.

Selection	ISR
Direct Install	0.96[912,913]
Virtual Assessment followed by Unverified Self-Install	0.803[914]
Requested Efficiency Kits	0.65[915]
Distributed Efficiency Kits (Income Eligible)	0.48[916]
Distributed School Efficiency Kit showerhead	0.25[917]

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:

$$\Delta kWh = 1.0 * ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.125 * 0.96$$
$$= 217\ kWh$$

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[918]

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

$$\Delta Water\ (gallons) = ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.96$$
$$= 1737\ gallons$$
$$\Delta kWh_{water} = 1737/1,000,000 * 5010$$
$$= 8.7\ kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

912 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.

913 Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report FINAL 2013-06-05

914 An equal weighted average of Direct Install and Efficiency Kit ISRs. Interest and applicability of measures confirmed through virtual assessment. Average of homes using 1 Showerhead & 2 Showerhead.

915 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.

916 Average of Guidehouse survey research for Peoples Gas, June 16, 2020 and Research from 2021 Ameren Illinois Income Qualified participant survey, available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf

917 Opinion Dynamics and Cadmus. 2018 AIC Residential Program Annual Impact Evaluation Report. April 30, 2019. Results from implementer-administered participant survey.

918 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'.

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[919] / 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[920]

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 = 217/273 * 0.0278

= 0.022 kW

FOSSIL FUEL SAVINGS

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = Percentage of DHW savings assumed to be fossil fuel

= 100 % for Fossil Fuel

= 0 % for Electric

= If unknown[921], use the following table:

919 72.6% is the proportion of hot 120F water mixed with 50.7F supply water to give 101F shower water.

920 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

921 Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[922]	76%	75%	60%	57%	72%
ComEd[923]	92%		89%		91%
People's Gas[924]	77%	74%	51%	50%	37%
Northshore Gas[925]	80%				
Nicor Gas[926]	80%				
All DUs					**72%**

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[927]

= 67% For shared water heater[928]

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 * 0.96

= 9.4 therms

922 Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

923 Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

924 Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

925 Ibid.

926 Comparable service area & customers to NSG, therefore using their survey data.

927 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%.

928 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

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) * 0.96

= 1737 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES

Source ID	Reference
1	2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011.
2	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
3	1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999.
4	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
5	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
6	2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011.
7	2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.

MEASURE CODE: RS-HWE-LFSH-V11-230101

REVIEW DEADLINE: 1/1/2025

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[929] = (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)

[929] 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)[930]
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%[931]
Instructions provided in all other Kit programs	10%[932]
All other	100%

3412 = Conversion from Btu to kWh

RE_electric = Recovery efficiency of electric hot water heater

= 0.98 [933]

A deemed savings assumption for non-kit programs, where site specific assumptions are not available would be as follows:

[930] 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.
[931] Opinion Dynamics and Cadmus. 2018 AIC Residential Program Annual Impact Evaluation Report. April 30, 2019. Results from implementer-administered participant survey.
[932] Opinion Dynamics. Impact and Process Evaluation of 2014 (PY7) Illinois Power Agency Rural Kits Program. April 19, 2016.
[933] 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.

FOSSIL FUEL 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 [934]

= 67% For MF homes[935]

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:

[934] 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%.

[935] 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.[936]

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.[937]

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:

[936] Visually determine whether it is insulated by foam (newer, rigid, and more effective) or fiberglass (older, gives to gently pressure, and not as effective)
[937] 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-ft^2/BTU).

R_{insul} = Overall thermal resistance coefficient after addition of tank wrap (Hr-°F-ft^2/BTU).

A_{base} = Surface area of storage tank prior to adding tank wrap (square feet)[938]

ΔT = Average temperature difference between tank water and outside air temperature (°F)

= 60°F [939]

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 [940]

The following table has default savings for various tank capacity and pre and post R-VALUES.

Capacity (gal)	Rbase	Rinsul	Abase (ft2)[941]	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

938 Area includes tank sides and top to account for typical wrap coverage.

939 Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

940 Electric water heaters have recovery efficiency of 98%.

941 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.

FOSSIL FUEL 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.[942]

DEEMED MEASURE COST

The incremental cost of the measure should be the actual program cost (including labor if applicable), or $30[943] plus $20 labor[944] if not available.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.22%.[945]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) *

942 Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead.

943 Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.

944 Estimate for contractor installation time.

945 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 = Percentage of DHW savings assumed to be electric

= 100 % for Electric

= 0 % for Fossil Fuel

= If unknown[946], use the following table:

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[947]	24%	25%	40%	43%	28%
ComEd[948]	8%		11%		9%
People's Gas[949]	23%	26%	49%	50%	63%
Northshore Gas[950]	20%				
Nicor Gas[951]	20%				
All DUs					28%

GPM_base_S = Flow rate of the basecase showerhead, or actual if available

Program	GPM
Direct-install, device only	2.24[952]
New Construction or direct install of device and low flow showerhead	Rated or actual flow of program-installed showerhead
Retrofit or TOS	2.35[953]

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

= 0.89 minutes[954]

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946 Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

947 Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

948 Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

949 Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

950 Ibid.

951 Comparable service area & customers to NSG, therefore using their survey data.

952 Based on measurements conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

953 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.

954 Average of the following sources: ShowerStart LLC survey; "Identifying, Quantifying and Reducing Behavioral Waste in the

Household = Average number of people per household

Household Unit Type[955]	Household
Single-Family - Deemed	2.56[956]
Multi-Family - Deemed	2.1[957]
Household type unknown	2.42[958]
Custom	Actual Occupancy or Number of Bedrooms[959]

Use Multifamily if: Building meets utility's definition for multifamily

SPCD = Showers Per Capita Per Day

= 0.6[960]

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[961]
Multifamily	1.3[962]
Household type unknown	1.64[963]
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

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.

955 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

956 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

957 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

958 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.

959 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.

960 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

961 Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

962 Ibid.

963 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.

= 101F [964]

SupplyTemp = Assumed temperature of water entering house

= 50.7°F [965]

RE_electric = Recovery efficiency of electric water heater

= 98% [966]

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[967]
Direct Install – Multi Family	0.95[968]
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[969]

964 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

965 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.

966 Electric water heaters have recovery efficiency of 98%.

967 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.

968 Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report FINAL 2013-06-05

969 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'.

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[970] / 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

= 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[971]

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

FOSSIL FUEL SAVINGS

ΔTherms = %FossilDHW * ((GPM_base_S * L_showerdevice)* Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = Percentage of DHW savings assumed to be fossil fuel

= 100 % for Fossil Fuel

[970] 72.6% is the proportion of hot 120F water mixed with 50.7F supply water to give 101F shower water.

[971] 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

= 0 % for Electric

= If unknown[972], use the following table:

	Location				
Utility	**Single Family**	**Single Family Low Income**	**Multi Family**	**Multi Family Low Income**	**Unknown**
Ameren[973]	76%	75%	60%	57%	72%
ComEd[974]	92%		89%		91%
People's Gas[975]	77%	74%	51%	50%	37%
Northshore Gas[976]	80%				
Nicor Gas[977]	80%				
All DUs					**72%**

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[978]

= 67% For MF homes[979]

Use Multifamily if: Building has shared DHW.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

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972 Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

973 Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

974 Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

975 Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

976 Ibid.

977 Comparable service area & customers to NSG, therefore using their survey data.

978 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%.

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

For example, a direct installed 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 & 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-V07-230101

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.[980]

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%.[981]

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 = Percentage of DHW savings assumed to be electric

= 100 % for Electric

980 Estimate of persistence of behavior change instigated by the shower timer.

981 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

= 0 % for Fossil Fuel

= If unknown[982], use the following table:

	Location				
Utility	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[983]	24%	25%	40%	43%	28%
ComEd[984]	8%		11%		9%
People's Gas[985]	23%	26%	49%	50%	63%
Northshore Gas[986]	20%				
Nicor Gas[987]	20%				
All DUs					28%

GPM = Flow rate of showerhead as used

= Custom, to be determined through evaluation. If data is not available use 1.93[988]

L_base = Number of minutes in shower without a shower timer

=7.8 minutes[989]

L_timer = Number of minutes in shower after shower timer

= Custom, to be determined through evaluation. If data is not available use 5.79.[990]

Household = Number in household using timer

Household Unit Type[991]	Household
Single-Family - Deemed	2.56[992]
Multi-Family - Deemed	2.1[993]

---

982 Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

983 Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

984 Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

985 Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

986 Ibid.

987 Comparable service area & customers to NSG, therefore using their survey data.

988 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

989 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.

990 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

991 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

992 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

993 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

Household Unit Type[991]	Household
Household type unknown	2.42[994]
Custom	Actual Occupancy or Number of Bedrooms[995]

Days/yr = 365.25

SPCD = Showers Per Capita Per Day

= 0.6[996]

UsageFactor = How often each participant is using shower timer

=Custom, to be determined through evaluation. If data is not available use 0.34[997]

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[998]

SupplyTemp = Assumed temperature of water entering house

= 50.7°F [999]

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.

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

Where

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

[994] 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.

[995] 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.

[996] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[997] Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

[998] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[999] 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.

=5,010[1000]

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

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 [1001] / 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[1002]

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

FOSSIL FUEL SAVINGS

ΔTherms = %FossilDHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas

1000 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'.

1001 72.6% is the proportion of hot 120F water mixed with 50.7F supply water to give 101F shower water.

1002 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

%FossilDHW = Percentage of DHW savings assumed to be fossil fuel

= 100 % for Fossil Fuel

= 0 % for Electric

= If unknown[1003], use the following table:

Utility	Location				
	Single Family	Single Family Low Income	Multi Family	Multi Family Low Income	Unknown
Ameren[1004]	76%	75%	60%	57%	72%
ComEd[1005]	92%		89%		91%
People's Gas[1006]	77%	74%	51%	50%	37%
Northshore Gas[1007]	80%				
Nicor Gas[1008]	80%				
All DUs					**72%**

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

= 78% For SF homes [1009]

= 67% For MF homes[1010]

Use Multifamily if: Building has shared DHW.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

[1003] Based on the average % electricity used for water 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. Please see subsequent table and citations for specific sources.

[1004] Provided by AEG from the 2020 Market Potential Study completed for AIC, as well as AIC Income Qualified Initiative: 2021 Participant Survey Results Memo (February 1, 2022) p. 17.

[1005] Commonwealth Edison Residential Baseline Study (2020). p.4.4 & 4.19; Section 4-7 Water Heating. Prepared by Itron.

[1006] Residential Appliance Saturation Survey of natural gas for space heating and water heating (2021). Note, Multifamily customers have a residential billing rate code and responded on the survey that they live in an apartment or condominium in a building that has either 2-4 or 5+ units.

[1007] Ibid.

[1008] Comparable service area & customers to NSG, therefore using their survey data.

[1009] 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%.

[1010] 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.

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-V05-230101

REVIEW DEADLINE: 1/1/2026

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.[1011]

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. [1012] Costs are per square foot.

[1011] 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

[1012] 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[1013]

[1013] 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

FOSSIL FUEL SAVINGS

The calculations are based on modeling runs using RSPEC! Energy Smart Pools Software that was created by the U.S. Department of Energy. [1014]

ΔTherms = SavingFactor x Size of Pool

Where

Savings factor = dependant on pool location and listed in table below:[1015]

Location	Therm / sq-ft
Indoor	2.61
Outdoor	1.01

Size of Pool = Actual. If unknown assume 392 ft^2 [1016]

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:[1017]

[1014] 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.

[1015] Calculations can be found in Residential Pool Covers.xlsx

[1016] 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/>

[1017] 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,[1018] 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.[1019]

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,[1020] 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.[1021]

The device can be installed in either an equal flow configuration or an unequal flow configuration. An 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.[1022]

DEEMED MEASURE COST

The incremental cost for this measure is $744 per unit.[1023]

LOADSHAPE

Load Shape R03 – Residential Electric DHW

[1018] 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.
[1019] G.Proskiw, "Technology Profile: Residential Greywater Heat Recovery Systems", June 1998, accessed April 2020.
[1020] 2019 Title 24, Part 6 CASE Report. "Drain Water Heat Recovery – Final Report."
[1021] Ibid
[1022] Ibid
[1023] 2019 Title 24, Part 6 CASE Report. "Drain Water Heat Recovery – Final Report.", average of 4 ft and 5 ft units. Page 21.

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 2.78%.[1024]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For electric water heating, annual energy savings per unit are calculated through the following formula:

$$\Delta kWh = \frac{(ShowerTemp - SupplyTemp) \times 8.33\frac{BTU}{gal \cdot °F} \times GPM \times T_{shower-length} \times N_{persons} \times N_{units} \times \text{SPCD} \times 365.25\frac{days}{yr} \times SF}{3412\frac{BTU}{kWh} \times RE}$$

Where:

ShowerTemp = assumed water temperature during shower

= 101°F[1025]

SupplyTemp = assumed temperature of cold water entering house

= 50.7°F[1026]

8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

GPM = gallon per minute, flow rate of showerhead

= 2.35 Gallon/minute[1027]

$T_{shower-length}$ = shower length in minutes

= 7.8 minutes[1028]

$N_{persons}$ = average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[1029]
Multi-Family – Deemed	2.1[1030]

[1024] Assume coincidence factor for DWHR units is the same with that of low flow showerheads (see Illinois Statewide Technical Reference Manual for Energy Efficiency, section 5.4.5, low flow showerheads)
[1025] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[1026] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.
[1027] Current Illinois Statewide Technical Reference Manual for Energy Efficiency, section 5.4.5, low flow showerheads, for Retrofit and New Construction
[1028] 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.
[1029] 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
[1030] 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)

Household Unit Type	Household
Household type unknown	2.42[1031]

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[1032]

365.25 = Days per year, on average.

SF = Water heating energy savings factor

= 0.466[1033]

3,412 = Conversion factor, 1 kWh equals 3,412 BTU

RE = Recovery efficiency of electric water heater:

= Actual or:

= 0.98[1034] for Electric Resistance

= 3.51[1035] for Electric HPWH

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 * 2.35 * 7.8 * 2.56 * 1 * 0.6 * 365.25 * 0.466) / (3412 * 0.98)

= 600.5 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

= $((GPM * T_{shower\text{-}length}) * N_{persons} * SPCD * 365.25) * 0.726$ [1036]/ GPH

= 286 for SF

= 234 for MF

[1031] 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.
[1032] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[1033] Codes and Standards Enhancement (CASE) Initiative, 2019 California Building Energy Efficiency Standards, Title 24, Part 6 Report. "Drain Water Heat Recovery - Final Report." July 2017, pg 17.
[1034] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.
[1035] Review of AHRI database shows that Electric Heat Pump Water Heaters support this recovery efficiency. For the raw data, and calculations, please see AHRI_ RES Water Heaters 2022.xlsx.
[1036] 72.6% is the proportion of hot 120F water mixed with 50.7F supply water to give 101F shower water.

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, When a DHWR unit is installed in a Single Family home, summer coincident peak demand savings can be calculated as follows:

ΔkW = (600.5 / 286) * 0.0278

= 0.0584 kW

FOSSIL FUEL SAVINGS

For gas water heating, annual energy savings per unit are calculated through the following formula:

$$\Delta \text{therms} = \frac{(\text{ShowerTemp} - \text{SupplyTemp}) \times 8.33\frac{\text{BTU}}{\text{gal}\cdot{}^\circ\text{F}} \times \text{GPM} \times T_{\text{shower-length}} \times N_{\text{persons}} \times N_{\text{units}} \times \text{SPCD} \times 365.25\frac{\text{days}}{\text{yr}} \times \text{SF}}{100{,}000\frac{\text{BTU}}{\text{therm}} \times \text{RE}}$$

Where:

100,000 = Conversion factor, 1 therm equals 100,000 BTU

RE = efficiency of gas water heater: 79% for single family[1037] and 67% for multi family[1038]

For example, for gas water heating, DHWR energy savings for single family home can be calculated as follows:

ΔTherms= ((101 – 50.7) * 8.33 * 2.35 * 7.8 * 2.56 * 1 * 0.6 * 365.25 * 0.466) / (100000 * 0.79)

= 25.4 therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-DHW-DWHR-V03-230101

REVIEW DEADLINE: 1/1/2026

[1037] 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 79%.

[1038] 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.

5.4.12 Recirculating Pump Controls

Description

Demand control recirculation pumps seek to reduce inefficiency by combining control via temperature and demand inputs, whereby the controller will not activate the recirculation pump unless both (a) the recirculation loop return water has dropped below a prescribed temperature (e.g., 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

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

Definition of Efficient Equipment

Re-circulating pump shall cycle on based on (a) the recirculation loop return water dropping below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

There are three alternative technologies that are considered in this characterization:

- Timer-based. This technology allows the user to program a schedule to perform recirculation during specific windows throughout the day.
- Aquastat-controlled. This type of control calls for recirculation when the water temperature at one point in the system falls below a certain pre-programmed setpoint.
- On-Demand. This technology senses the demand as water flow through the CDHW system. These types of system are most adequate on small central water heating systems.

Definition of Baseline Equipment

The base case for this measure category is existing, uncontrolled recirculation pumps on either electric or gas-fired Central Domestic Hot Water systems (CDHW).

Deemed Lifetime of Efficient Equipment

The effective useful life is 15 years.[1039]

Deemed Measure Cost

The average cost of the demand controller circulation kit is $1,442 with an installation cost of $768 for a total measure cost of $2,210.[1040]

[1039] Benningfield Group. (2009). *PY 2009 Monitoring Report: Demand Control for Multifamily Central Domestic Hot Water.* Folsom, CA: Prepared for Southern California Gas Company, October 30, 2009.

[1040] The incremental costs were averaged based on the following multi-family, dormitory and hospitality building studies-

- Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation public project report.* Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.
- Studies performed in multiple dormitory buildings in the California region for Southern California Gas' PREPS Program, 2012.
- Evaluation of New DHW System Controls in Hospitality and Commercial Buildings. Prepared for: Minnesota Department of Commerce, Division of Energy Resources, 2018.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{heater} * + \Delta kWh_{pump}$$

$$\Delta kWh_{heater} = \frac{(T_{out} - T_{in}) * GPD * HouseHold * 365.25 * \gamma Water * 1 * \left(\frac{1}{UEF_{heater}}\right)}{3412} * SF$$

Where:

T_{OUT} = Tank temperature

= 125°F

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

= 50.7°F [1041]

GPD = Gallons hot water per day per person

Household = Average number of people per household (2.59 people per household[1042])

Household Unit Type	Household
Single-Family - Deemed	2.56
Multifamily - Deemed	2.1
Custom	Actual Occupancy or Number of Bedrooms.

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

= 8.33 lbs/gal

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

UEF_{heater} = Rated efficiency of water heater expressed as Uniform Energy Factor (UEF);

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

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[1043]
Residential Electric Storage	≤55 gallon tanks	Very small	UEF = 0.8808 – (0.0008 * Rated Storage Volume in Gallons)

[1041] 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.

[1042] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[1043] 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.

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[1043]
Water Heaters ≤ 75,000 Btu/h		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 [1044]	Very small	UEF = 1.9236 – (0.0011 * Rated Storage Volume in Gallons)
		Low	UEF = 2.0440 – (0.0011 * Rated Storage Volume in Gallons)
		Medium	UEF = 2.1171 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 2.2418 – (0.0011 * Rated Storage Volume in Gallons)
Residential Electric Instantaneous Water Heaters	≤12kW and ≤2 gal	All other	UEF = 0.91
		High	UEF = 0.92
Residential-duty Commercial Electric Instantaneous Water Heaters	> 12kW and ≤58.6 kW and ≤2 gal	All	UEF = 0.80

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:[1045]

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

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

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

= Actual

3412 = Converts Btu to kWh

SF = Savings factor based on Building type

Building Type	Savings Factor[1046]
Single-Family - Deemed	9%
Multifamily - Deemed	9%

[1044] It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline.

[1045] Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1.

[1046] The savings factor from ACEEE Hot Water Forum. Control Methods, Code Requirements and Energy Savings. 9% is assumed to be the savings factor for multifamily and Single-Family buildings.

$$\Delta kWh_{pump} = \frac{HP_{recirculating} * 0.75 * (8760 - Pump_{hrs\ controlled})}{Motor_{eff}}$$

Where:

$HP_{recirculating}$ = the size of the recirculating pump in HP

0.75 = Conversion factor kW/HP

8760 = Hours of operation of uncontrolled recirculating pump

$Pump_{hrs\ controlled}$ = The table below corresponds to the control types for commercial buildings

Hours of operation[1047]	
Timer	6,570
Aquastat-Controlled	1,095
On Demand	122

$Motor_{eff}$ = The efficiency of the pump motor, use actual.

NATURAL GAS SAVINGS

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

$$\Delta Therms = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma Water * 1 * \left(\frac{1}{EF_{Gas}}\right)}{100{,}000} * SF$$

Where:

100,000 = Converts Btu to Therms

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

Use actual or the minimum efficiency from the Federal Standard

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[1048]
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 gallon tanks	Very small	UEF = 0.6470 – (0.0006 * Rated Storage Volume in Gallons)
		Low	UEF = 0.7689 – (0.0005 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.7897 – (0.0004 * Rated Storage Volume in Gallons)
		High	UEF = 0.8072 – (0.0003 * Rated Storage Volume in Gallons)
Residential-duty Commercial High Capacity Storage Gas-Fired Storage Water Heaters > 75,000 Btu/h	≤120 gallon tanks	Very small	UEF = 0.2674 – (0.0009 * Rated Storage Volume in Gallons)
		Low	UEF = 0.5362 – (0.0012 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.6002 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 0.6597 – (0.0009 * Rated Storage Volume in Gallons)
Commercial	>120 gallon tanks	All	80% $E_{thermal}$,

[1047] The Hours of operation of recirculating pump for commercial buildings in general from Research and Analysis of the Benefits of Appliance Standards for Domestic Hot Water Circulator Pumps. Energy Solutions (October 2021)

[1048] 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.

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor[1048]
Gas Storage Water Heaters >75,000 Btu/h and ≤155,000 Btu/h			Standby Losses = (Q /800 + 110√Rated Storage Volume in Gallons)
Commercial Gas Storage Water Heaters >155,000 Btu/h			
Residential Gas Instantaneous Water Heaters ≤ 200,000 Btu/h	≤2 gal	Very low	UEF = 0.80
		All other	UEF = 0.81
Commercial Gas Instantaneous Water Heaters > 200,000 Btu/h	<10 gal	All	80% $E_{thermal}$
	≥10 gal	All	78% $E_{thermal}$

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:[1049]

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

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

ηHeat = Heating system efficiency including duct loss

= Actual

SF = Savings factor based on Building type

Building Type	Savings Factor[1050]
Single-Family - Deemed	9%
Multifamily - Deemed	9%

[1049] Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1.

[1050] The savings factor from ACEEE Hot Water Forum. Control Methods, Code Requirements and Energy Savings. 9% is assumed to be the savings factor for multifamily and Single-Family buildings.

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-CDHW-V01-230101

REVIEW DEADLINE: 1/1/2025

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

Please note that this measure characterization contains specific assumptions that were negotiated as a compromise between the utilities and stakeholders and also reflects input from community-based organizations. The compromise is designed to allow for a gradual change in Income Qualified programming and to address the unique challenges that an abrupt change makes within the context of the Illinois CPAS savings goal structure. Such compromise shall not be taken as precedent for future non-consensus discussions.

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 not in a store 'easily accessed by income qualified communities' (see discussion below)) a deemed split of 96% Residential and 4% Commercial assumptions should be used.[1051] For stores easily accessed by income qualified communities, 100% of sales are assumed to be Income Qualified (IQ) residential.

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 or equivalent to the most recent version of ENERGY STAR specifications. 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. In September 2019 this decision was revoked in a new DOE Final Rule. However, in May 2022 DOE reversed this decision by issuing a Final rule for both the broadened General Service Lamp definition as well as the implementation of the 45 lumen per watt backstop. DOE stated that it will use its enforcement discretion to minimize impacts on the supply chain and effectively allow companies to continue the manufacture and import of noncompliant bulbs through the remainder of 2022, and allow retailers to continue selling them with limited enforcement until July 2023.

Non-Income Qualified Programs

This TRM assumes that non-income qualified participants would continue to have access to baseline / noncompliant bulbs through retail until 6/30/2023 after which the baseline for new purchases becomes an LED (since only CFL and LED are able to meet the 45 lu/watt standard and CFLs now make up <1% of the market). For purchases made before this date it is assumed that stockpiles would remain through the remainder of 2023 such that the measure life for 2023 purchases is reduced to 2 years.

Direct Install programs where it can be shown that the LED is replacing working inefficient lighting should continue to use the existing inefficient lighting as baseline and also assume a measure life of 2 years.

Income Qualified Programs

Through 2025, Retail programs in stores 'easily accessed by income qualified communities' (as defined below), and

[1051] 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'.

Kit, School and Foodbank programs, will continue to assume a halogen baseline and apply a measure life of 8 years.

A store is considered easily accessed by income qualified communities[1052]:

a. For Ameren:
   i. if it is a retail store that is closest to a community with a zip code that has 65% of family households with an income less than or equal to 299% of the Federal poverty level for their household size (Applies to big box (e.g., Walmart), club (e.g., Costco), DIY (e.g., Home Depot), hardware and grocery stores); or
   ii. If it is a "dollar store" in the AIC service area; or
   iii. If it is a "thrift store" in the AIC service area.
b. For ComEd:
   i. if it is a retail store is within a zip code where at least 60% or more of the households are at or below 80% Area Median Income (AMI); or
   ii. If it is a "dollar store" in the ComEd service area; or
   iii. If it is a "thrift store" in the ComEd service area.

100% of sales from such stores as defined above will count as IQ lighting.

Direct Install programs where it can be shown that the LED is replacing working inefficient lighting should continue to use the existing inefficient lighting as baseline and also assume a measure life of 8 years.

<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 and 100 percent in IECC 2021) of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps or not less than 75 percent (90 percent in IECC 2018 and 100 percent in IECC 2021) 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) or 100% (IECC 2021) of the New Construction baseline is an LED and therefore savings are reduced by that percentage for bulbs provided in New Construction projects. Any New Construction project utilitizing IECC 2021 code should therefore not include savings from this measure.

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.

However, for all purchases through 2025 the measure life is assumed to be two years for non-income eligible populations and eight years for income eligible populations.

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:[1053]

[1052] Utilities to provide list of all stores that are easily accessed by income qualified communities, as defined above, by December 31, 2022, with one of the utility's quarterly reports and to the utility's independent evaluator. The Utilities will update the list of stores annually, by December 31 of each year of the current portfolio cycle in a similar fashion.

[1053] 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.

Bulb Type	Year	Incandescent	LED	Incremental Cost	Incremental Cost for New Construction (IECC 2015)	Incremental Cost for New Construction (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,[1054], 0.273 for exterior bulbs[1055] and 0.117 for unknown[1056]. 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.[1057]

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below.

1054 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.

1055 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.

1056 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.

1057 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
Decorative (Shape ST)	250	499	6.5	40	14.9	9.9	33.5	8.4	3.4
	500	999	8.8	60	21.6	13.9	51.2	12.8	5.1
	1000	1500	10.0	100	32.5	19.0	90.0	22.5	9.0
Decorative (Shape S)	50	75	1.0	11	3.5	2.0	10.0	2.5	1.0
	100	120	1.2	15	4.7	2.6	13.8	3.5	1.4
	120	340	2.25	25	7.9	4.5	22.8	5.7	2.3

Directional Lamps - ENERGY STAR Minimum Luminous Efficacy = 70Lm/W for <90 CRI lamps and 61 Lm/W for >=90CRI lamps.

For Directional R, BR, and ER lamp types:[1058]

[1058] 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.[1059] 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.[1060]

$$\text{Wattsbase} =$$

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

[1059] See 'ESLampCenterBeamTool.xls'.

[1060] 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	In Service Rate (ISR) [1061]
Retail (Time of Sale)	97.9%[1062]
Direct Install	94.5%[1063]

[1061] In Service Rates now represent the lifetime In Service Rates with the second and third year installations discounted by the Real Discount Rate of 0.46%. Lifetime 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. For all other programs 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.

[1062] 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).

[1063] 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 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.

<table>
<tr><th colspan="2">Program</th><th>In Service Rate (ISR) [1061]</th></tr>
<tr><td colspan="2">Virtual Assessment followed by Unverified Self-Install</td><td>97.9%[1064]</td></tr>
<tr><td rowspan="5">Efficiency Kits[1065]</td><td>LED Distribution[1066]</td><td>82.8%</td></tr>
<tr><td>School Kits[1067]</td><td>83.8%</td></tr>
<tr><td>Direct Mail Kits[1068]</td><td>91.8%</td></tr>
<tr><td>Direct Mail Kits, Income Qualified[1069]</td><td>64.8%</td></tr>
<tr><td>Community Distributed Kits[1070]</td><td>95.0%</td></tr>
</table>

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1071] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1072]

ComEd: 1.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

Installation Location	Annual hours of use (HOU)
Residential and In-Unit Multi Family	763[1073]

[1064] An equal weighted average of Direct Install and Direct Mail Kit ISRs. Interest and applicability of measures confirmed through virtual assessment.

[1065] 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.

[1066] Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

[1067] 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.

[1068] Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

[1069] Research from 2021 Ameren Illinois Income Qualified participant survey (customer self-report), available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf

[1070] Kits distributed in a community setting, targeted to income qualified communities. Research from 2018 Ameren Illinois Income Qualified participant survey.

[1071] 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.

[1072] Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY5,6 and 8 for Ameren.

[1073] 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.

Installation Location	Annual hours of use (HOU)
Exterior	2,475[1074]
Unknown	1,020[1075]

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

Bulb Location	WHFe
Interior single family	1.06 [1076]
Multifamily in unit	1.04 [1077]
Exterior or uncooled location	1.0
Unknown location	1.046[1078]

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

HEATING PENALTY

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

ΔkWh[1079] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

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1074 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.

1075 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.

1076 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)

1077 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)

1078 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.

1079 Negative value because this is an increase in heating consumption due to the efficient lighting.

= 49% for interior location [1080]

= 0% for exterior location

= 42% for unknown location [1081]

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [1082]

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[1083]	N/A	N/A	1.28

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location with a 2016 heat pump:

ΔkWh = - (((75 - 13) / 1000) * 0.840 * (1 – 0.011) * 763 * 0.49) / 2.04

= - 9.4 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[1084]
Multifamily in unit	1.07[1085]

[1080] 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.

[1081] 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.

[1082] 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.

[1083] 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.

[1084] 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.

[1085] As above but using estimate of 45% of multifamily buildings in Illinois having central cooling (based on data from "Table

Bulb Location	WHFd
Exterior or uncooled location	1.0
Unknown location	1.083[1086]

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[1087], 0.273 for exterior bulbs,[1088] and 0.117 for unknown.[1089]

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

FOSSIL FUEL 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[1090]

= 0% for exterior location

= 42% for unknown location[1091]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

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)

1086 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.

1087 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.

1088 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.

1089 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.

1090 Average result from REMRate modeling of several different configurations and IL locations of homes

1091 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 [1092]

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

For non-income eligible populations, no O&M costs should be applied.

For income eligible populations, an annual baseline cost of $1.74 for decorative and $3.53 for directional should be applied.

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-V15-230101

REVIEW DEADLINE: 1/1/2024

[1092] 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

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.[1093]

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.[1094]

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 100%.[1095]

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:

1093 Estimate of remaining life of existing unit being replaced.

1094 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.

1095 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[1096]
CFL (dual sided)	14W[1097]
CFL (single sided)	7W
Unknown	7W

WattsEE = Actual wattage if known, if singled sided or unknown assume 2W, if dual sided assume 4W.[1098]

HOURS = Annual operating hours

= 8766

WHF_e = Waste heat factor for energy; accounts for cooling savings from efficient lighting.

= 1.04[1099]

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 Fossil Fuel section):

ΔkWh[1100] = - (((WattsBase - WattsEE) / 1000) * Hours * HF) / ηHeat

Where:

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

= 49%[1101]

1096 Based on review of available product.

1097 Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

1098 Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

1099 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)

1100 Negative value because this is an increase in heating consumption due to the efficient lighting.

1101 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: [1102]

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[1103]	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[1104]

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

[1102] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[1103] 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.

[1104] 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

FOSSIL FUEL 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% [1105]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1106]

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)

[1105] Average result from REMRate modeling of several different configurations and IL locations of homes

[1106] 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[1107]	1.37 years[1108]

MEASURE CODE: RS-LTG-LEDE-V03-190101

REVIEW DEADLINE: 1/1/2024

[1107] 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).
[1108] 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

Please note that this measure characterization contains specific assumptions that were negotiated as a compromise between the utilities and stakeholders and also reflects input from community-based organizations. The compromise is designed to allow for a gradual change in Income Qualified programming and to address the unique challenges that an abrupt change makes within the context of the Illinois CPAS savings goal structure. Such compromise shall not be taken as precedent for future non-consensus discussions.

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 not in a store 'easily accessed by income qualified communities' (see discussion below)) a deemed split of 97% Residential and 3% Commercial assumptions should be used.[1109] For stores easily accessed by income qualified communities, 100% of sales are assumed to be Income Qualified (IQ) residential.

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 or equivalent to the most recent version of ENERGY STAR specifications. 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. In December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that this more stringent standard was not economically justified. However, in May 2022 DOE reversed this decision by issuing a Final rule for both the broadened General Service Lamp definition as well as the implementation of the 45 lumen per watt backstop. DOE stated that it will use its enforcement discretion to minimize impacts on the supply chain and effectively allow companies to continue the manufacture and import of noncompliant bulbs through the remainder of 2022, and allow retailers to continue selling them with limited enforcement until July 2023.

Non-Income Qualified Programs

This TRM assumes that non-income qualified participants would continue to have access to baseline / noncompliant bulbs through retail until 6/30/2023 after which the baseline for new purchases becomes an LED (since only CFL and LED are able to meet the 45 lu/watt standard and CFLs now make up <1% of the market). For purchases made before this date it is assumed that stockpiles would remain through the remainder of 2023 such that the measure life for 2023 purchases is reduced to 2 years.

Direct Install programs where it can be shown that the LED is replacing working inefficient lighting should continue to use the existing inefficient lighting as baseline and also assume a measure life of 2 years.

[1109] 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'.

Income Qualified Programs

Through 2025, Retail programs in stores 'easily accessed by income qualified communities' (as defined below), and Kit, School and Foodbank programs, will continue to assume a halogen baseline and apply a measure life of 8 years.

A store is considered easily accessed by income qualified communities[1110]:

c. For Ameren:
    i. if it is a retail store that is closest to a community with a zip code that has 65% of family households with an income less than or equal to 299% of the Federal poverty level for their household size (Applies to big box (e.g., Walmart), club (e.g., Costco), DIY (e.g., Home Depot), hardware and grocery stores); or
    ii. If it is a "dollar store" in the AIC service area; or
    iii. If it is a "thrift store" in the AIC service area.
d. For ComEd:
    i. if it is a retail store is within a zip code where at least 60% or more of the households are at or below 80% Area Median Income (AMI); or
    ii. If it is a "dollar store" in the ComEd service area; or
    iii. If it is a "thrift store" in the ComEd service area.

100% of sales from such stores as defined above will count as IQ lighting.

Direct Install programs where it can be shown that the LED is replacing working inefficient lighting should continue to use the existing inefficient lighting as baseline and also assume a measure life of 8 years.

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 and 100 percent in IECC 2021) of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps or not less than 75 percent (90 percent in IECC 2018 and 100 percent in IECC 2021) 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) or 100% (IECC 2021) of the New Construction baseline is an LED and therefore savings are reduced by that percentage for bulbs provided in New Construction projects. Any New Construction project utilizing IECC 2021 code should therefore not include savings from this measure.

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.

However, for all purchases through 2025 the measure life is assumed to be two years for non-income eligible populations and eight years for income eligible populations.

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:[1111]

[1110] Utilities to provide list of all stores that are easily accessed by income qualified communities, as defined above, by December 31, 2022, with one of the utility's quarterly reports and to the utility's independent evaluator. The Utilities will update the list of stores annually, by December 31 of each year of the current portfolio cycle in a similar fashion.

[1111] Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

Year	EISA Compliant Halogen	LED A-Lamp	Incremental Cost	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,[1112] 0.273 for exterior bulbs,[1113] and 0.135 for unknown,[1114]

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:[1115]

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

[1112] 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.

[1113] 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.

[1114] 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.

[1115] 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.

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)
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.

Program		In Service Rate (ISR)[1116]s
Retail (Time of Sale)		97.9%[1117]
Direct Install		94.5%[1118]
Virtual Assessment followed by Unverified Self-Install		97.9%[1119]
Efficiency Kits[1120]	LED Distribution[1121]	82.8%
	School Kits[1122]	83.8%
	Direct Mail Kits[1123]	91.8%
	Direct Mail Kits, Income Qualified[1124]	60%

[1116] In Service Rates now represent the lifetime In Service Rates with the second and third year installations discounted by the Real Discount Rate of 0.46%. Lifetime 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. For all other programs Tthe 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.

[1117] 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).

[1118] 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.

[1119] An equal weighted average of Direct Install and Direct Mail Kit ISRs. Interest and applicability of measures confirmed through virtual assessment.

[1120] 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.

[1121] Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

[1122] 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.

[1123] Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

[1124] Research from 2021 Ameren Illinois Income Qualified participant survey (customer self-report), available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf

Program		In Service Rate (ISR)[1116]s
	Community Distributed Kits[1125]	95.0%
Food Bank / Pantry Distribution[1126]		97.9%[1127]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1128] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1129]

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[1130]
Exterior	2,475[1131]
Unknown	1,159[1132]

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

Bulb Location	WHFe
Interior single family	1.06 [1133]
Multifamily in unit	1.04 [1134]

1125 Kits distributed in a community setting, targeted to income qualified communities. Research from 2018 Ameren Illinois Income Qualified participant survey.

1126 Free bulbs provided through local food banks and food pantries.

1127 1st year ISR is determined based on online surveys conducted for ComEd CY2018 Food Bank LED Distribution program. See 'CY2018 ComEd Foodbank LED Dist Survey Results_Navigant'.

1128 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.

1129 Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY8 for Ameren.

1130 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.

1131 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.

1132 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.

1133 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)

1134 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[1135]

> **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

HEATING PENALTY

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

ΔkWh[1136] = - (((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[1137]

= 0% for exterior or unheated location

= 42% for unknown location[1138]

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use:[1139]

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

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)

1135 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.

1136 Negative value because this is an increase in heating consumption due to the efficient lighting.

1137 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.

1138 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.

1139 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.

Resistance	N/A	N/A	1.00
Unknown[1140]	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.

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[1141]
Multifamily in unit	1.07[1142]
Exterior or uncooled location	1.0
Unknown location	1.093[1143]

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF
Interior	0.128[1144]
Exterior	0.273[1145]
Unknown	0.135[1146]

1140 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.

1141 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.

1142 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)

1143 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.

1144 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.

1145 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.

1146 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.

Other factors as defined above

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

ΔkW = ((29 - 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.

FOSSIL FUEL 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[1147]

= 0% for exterior location

= 42% for unknown location[1148]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1149]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

For non-income eligible populations, no O&M costs should be applied.

For income eligible populations, an annual baseline cost of $1 should be applied.

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:

[1147] Average result from REMRate modeling of several different configurations and IL locations of homes

[1148] 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.

[1149] 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

MEASURE CODE: RS-LTG-LEDA-V14-230101

REVIEW DEADLINE: 1/1/2024

5.5.9 LED Fixtures

DESCRIPTION

Please note that this measure characterization contains specific assumptions that were negotiated as a compromise between the utilities and stakeholders and also reflects input from community-based organizations. The compromise is designed to allow for a gradual change in Income Qualified programming and to address the unique challenges that an abrupt change makes within the context of the Illinois CPAS savings goal structure. Such compromise shall not be taken as precedent for future non-consensus discussions.

This characterization provides savings assumptions for LED Fixtures and is broken into five ENERGY STAR fixture types: Indoor Fixtures (including track lighting, wall-wash, sconces, ceiling and fan lights), Task and Downlight Under Cabinet Fixtures (linear under cabinet fixtures are exempt from EISA and so can be found in measure 5.5.13), Outdoor Fixtures (including flood light, hanging lights, security/path lights, outdoor porch lights), and Downlight Fixtures.

Where the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program not in a store 'easily accessed by income qualified communities' (see discussion below)) 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.[1150] For stores easily accessed by income qualified communities, 100% of sales are assumed to be Income Qualified (IQ) residential.

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 or equivalent to the most recent version of ENERGY STAR specifications. Specifications are as follows:

Fixture Category	Lumens/Watt
Indoor	65
Downlight 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. In September 2019 this decision was revoked in a DOE Final Rule. However, in May 2022 DOE reversed this decision by issuing a Final rule for both the broadened General Service Lamp definition as well as the implementation of the 45 lumen per watt backstop. DOE stated that it will use its enforcement discretion to minimize impacts on the supply chain and

[1150] 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'.

effectively allow companies to continue the manufacture and import of noncompliant bulbs through the remainder of 2022, and allow retailers to continue selling them with limited enforcement until July 2023.

Non-Income Qualified Programs

This TRM assumes that non-income qualified participants would continue to have access to baseline / noncompliant bulbs through retail until 6/30/2023 after which the baseline for new purchases becomes an LED (since only CFL and LED are able to meet the 45 lu/watt standard and CFLs now make up <1% of the market). For purchases made before this date it is assumed that stockpiles would remain through the remainder of 2023 such that the measure life for 2023 purchases is reduced to 2 years.

Direct Install programs where it can be shown that the LED is replacing working inefficient lighting should continue to use the existing inefficient lighting as baseline and also assume a measure life of 2 years.

Income Qualified Programs

Through 2025, Retail programs in stores 'easily accessed by income qualified communities' (as defined below), and Kit, School and Foodbank programs, will continue to assume a halogen baseline and apply a measure life of 8 years.

A store is considered easily accessed by income qualified communities[1151]:

a. For Ameren:
   iv. if it is a retail store that is closest to a community with a zip code that has 65% of family households with an income less than or equal to 299% of the Federal poverty level for their household size (Applies to big box (e.g., Walmart), club (e.g., Costco), DIY (e.g., Home Depot), hardware and grocery stores); or
   v. If it is a "dollar store" in the AIC service area; or
   vi. If it is a "thrift store" in the AIC service area.
b. For ComEd:
   vii. if it is a retail store is within a zip code where at least 60% or more of the households are at or below 80% Area Median Income (AMI); or
   viii. If it is a "dollar store" in the ComEd service area; or
   ix. If it is a "thrift store" in the ComEd service area.

100% of sales from such stores as defined above will count as IQ lighting.

Direct Install programs where it can be shown that the LED is replacing working inefficient lighting should continue to use the existing inefficient lighting as baseline and also assume a measure life of 8 years.

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 and 100 percent in IECC 2021) of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps or not less than 75 percent (90 percent in IECC 2018 and 100 percent in IECC 2021) 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) or 100% (IECC 2021) of the New Construction baseline is an LED and therefore savings are reduced by that percentage for bulbs provided in New Construction projects. Any New Construction project utilizing IECC 2021 code should therefore not include savings from this measure.

[1151] Utilities to provide list of all stores that are easily accessed by income qualified communities, as defined above, by December 31, 2022, with one of the utility's quarterly reports and to the utility's independent evaluator. The Utilities will update the list of stores annually, by December 31 of each year of the current portfolio cycle in a similar fashion.

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 downlight task and under cabinet, and 49,000 for outdoor fixtures.[1152]

However, for all purchases through 2025 the measure life is assumed to be two years for non-income eligible populations and eight years for income eligible populations.

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[1153]	$6.50	$2.60
Downlight Task /Under Cabinet	$18[1154]	$4.50	$1.80
Outdoor	$26	$6.50	$2.60
Downlight	$13	$3.25	$1.30

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,[1155] 0.273 for exterior fixtures,[1156] and 0.127 for unknown.[1157]

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

[1152] Average rated lives are based on the average rated lives of fixtures available on the ENERGY STAR qualifying list as of 2/26/2018.

[1153] 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.

[1154] Incremental costs for task/under cabinet and downlight fixtures are from the 2018 Michigan Energy Measures Database.

[1155] 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.

[1156] 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.

[1157] 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.

within the fixture category;[1158] see table below.

$Watts_{EE}$ = Actual wattage of LED fixture purchased / installed - If unknown, use default provided below:[1159]

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
Downlight Task and 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[1160]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1161] of the Utility Jurisdiction.

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1162]

ComEd: 0.7%

Ameren: 6.6%

All other programs = 0

Hours = Average hours of use per year

Fixture Category	Hours
Indoor and Downlight	926[1163]
Task/Under Cabinet	730[1164]
Outdoor	2,475[1165]

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

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1158 See "Analysis" tab within file Residential LED Fixtures_Analysis_June 2018.xlsx for baseline calculations.

1159 Average of ENERGY STAR product category watts for products at or above the version 2.1 efficacy specification

1160 ISR recommendation for fixtures in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-22.

1161 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.

1162 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.

1163 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

1164 Task/under cabinet hours of use are estimated at 2 hours per day.

1165 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.

Bulb Location	WHFe
Interior single family	1.06 [1166]
Multifamily in unit	1.04 [1167]
Exterior or uncooled location	1.0
Unknown location	1.051[1168]

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

HEATING PENALTY

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

ΔkWh[1169] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

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

= 49%[1170] for interior location

= 0% for exterior or unheated location

= 42%[1171] for unknown location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use:[1172]

[1166] 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)

[1167] 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)

[1168] 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.

[1169] Negative value because this is an increase in heating consumption due to the efficient lighting.

[1170] 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.

[1171] 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.

[1172] 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
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[1173]	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.

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[1174]
Multifamily in unit	1.07[1175]
Exterior or uncooled location	1.0
Unknown location	1.093[1176]

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF
Interior	0.119[1177]

1173 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.

1174 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.

1175 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)

1176 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.

1177 Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs. Average of values for standard and specialty bulbs.

Bulb Location	CF
Exterior	0.273[1178]
Unknown	0.127[1179]

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.

FOSSIL FUEL 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[1180]

= 0% for exterior location

= 42% for unknown location[1181]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1182]

[1178] 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.

[1179] 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.

[1180] Average result from REMRate modeling of several different configurations and IL locations of homes

[1181] 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.

[1182] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

For non-income eligible populations, no O&M costs should be applied.

For income eligible populations, an annual baseline cost of $1.90 should be applied.

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-LDFX-V06-230101

Review Deadline: 1/1/2024

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.[1183]

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: [1184, 1185]

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

[1183] See ‘Christmas Lights Buying Guide – Hayneedle’.
[1184] See ‘Christmas Lights Buying Guide – Hayneedle’.
[1185] 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.[1186]

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[1187]
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[1188]

Type	Incandescent Bulb (Watts)	LED Bulb (Watts)
Mini	0.40	0.07
C7	5.00	0.48
C9	7.00	2.00

Bulbs = Actual quantity of bulbs on the string. If baseline is unknown, assume same as

[1186] 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'

[1187] See file Holiday Lights Research and Calcs_2018.xlsx for CLEAResult research on holiday string lighting costs.

[1188] Average wattages from PGE "Cost of holiday lights", published December 2021, and PA PUC Feb 2021.

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:[1189]

ComEd:	1.6%
Ameren:	13.1%

Hours = Average hours of use per year

= 210 hours[1190]

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 = ((0.40 * 50) – (0.07 * 50))/1000) * 1.00 * (1 - 0) * 210 * 1.0

= 3.5 kWh

HEATING PENALTY

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

ΔkWh[1191] = - (((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[1192]
= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available, use:[1193]

[1189] Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY8 for Ameren.

[1190] 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."

[1191] Negative value because this is an increase in heating consumption due to the efficient lighting.

[1192] 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.

[1193] 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[1194]	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 = - ((((0.40 * 50) – (0.07 * 50))/1000) * 1.00 * (1 - 0) * 210 * 0.49) / 2.0

= - 0.8 kWh

Summer Coincident Peak Demand Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Fossil Fuel 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 [1195]

= 0% for exterior location

0.03412 = Converts kWh to Therms

ηHeat = Actual heating system efficiency

= 70% [1196]

[1194] 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.

[1195] Average result from REMRate modeling of several different configurations and IL locations of homes.

[1196] 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:

Δtherms = - ((((0.40 * 50) – (0.07 * 50))/1000) * 1.00 * (1 - 0) * 210 * 0.49 * 0.03412) / 0.70

= - 0.08 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-LTG-LEDH-V03-230101

REVIEW DEADLINE: 1/1/2025

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.[1197]

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:[1198]

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.[1199]

[1197] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2. and p.3.
[1198] Average cost data provided in Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March 2018.
[1199] 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%[1200]	7.6%	6.4%	98.0%[1201]
Direct Install	96.9%[1202]			
School Kits	60%[1203]	13%	11%	84%

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1204] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1205]

ComEd: 2.0%

Ameren: 13.1%

Hours = Average hours of use per year

= 4,380[1206]

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

Bulb Location	WHFe
Interior single family	1.06 [1207]

[1200] 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).

[1201] 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.

[1202] 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.

[1203] 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

[1204] 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.

[1205] Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY5,6 and 8 for Ameren (see for more information).

[1206] Assumes nightlight is operating 12 hours per day, consistent with the 2016 Pennsylvania TRM.

[1207] 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 [1208]
Unknown location	1.054[1209]

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 Fossil Fuel section):

ΔkWh[1210] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / ηHeat

Where:=(

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

= 49% for interior[1211]

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [1212]

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[1213]	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)

1208 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)

1209 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.

1210 Negative value because this is an increase in heating consumption due to the efficient lighting.

1211 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.

1212 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.

1213 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[1214]
Multifamily in unit	1.07[1215]
Unknown location	1.098[1216]

CF = Summer Peak Coincidence Factor for measure.

= 0

FOSSIL FUEL 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[1217]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency

= 0.70 [1218]

Other factors as defined above

1214 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.

1215 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)

1216 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.

1217 Average result from REMRate modeling of several different configurations and IL locations of homes

1218 This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

For example, a 0.3W LED nightlight is direct installed in single family interior location with gas heating at 70% total efficiency:

$$\Delta therms = - (((7 – 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49 * 0.03412) / 0.70$$

$$= - 0.68 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE: RS-LTG-NITL-V01-190101

REVIEW DEADLINE: 1/1/2025

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.[1219] For all other applications, lifetimes are capped at 10 years.[1220]

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.[1221]

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,[1222] 0.273

[1219] 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.

[1220] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

[1221] Estimate based on review of available product and estimates provided in King J., ACEEE, "Energy Impacts of Smart Home Technologies", April 2018.

[1222] 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,[1223] and 0.135 for unknown.[1224]

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[1225]

HOURS = Average hours of use per year

Installation Location	Hours
Residential and in-unit Multi Family	1,089[1226]
Exterior	2,475[1227]
Unknown	1,159[1228]

SVGe = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below

= 0.37[1229]

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

Program	Weighted Average 1st year In Service Rate (ISR)[1230]
Retail (Time of Sale)	98.0%

[1223] 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.

[1224]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.

[1225] Connecticut LED Lighting Study Report (R154). Average connected wattage of lamps in dining room, living space, bedroom, bathroom, and kitchen spaces.

[1226] 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.

[1227] 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.

[1228] 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.

[1229] Based on Lockheed Martin, 'Home Energy Management System/Cmart Lighting Pilot for National Grid's Massachusetts and Rhode Island Residential Energy Efficiency Programs', Final Report, March 18, 2019. The study found the energy consumption of the LED to be 11.5/1000 * 1200 hours = 13.8kWh. Savings from the smart lamp included both geo fencing (96% of studied homes providing 5.1kWh of savings) and in-room occupancy (3% of studied homes providing 6.6kWh of savings), for a total savings of 5.1kWh (0.96*5.1 + 0.03*6.6). As a percentage of the LED consumption this is 5.1/13.8 = 37%.

[1230] ISRs are consistent with the LED Screw Based Standard Lamp measure, however since 2nd and 3rd year savings for this

Program		Weighted Average 1st year In Service Rate (ISR) [1230]
Direct Install		94.5%
Efficiency Kits	LED Distribution	83%
	School Kits	84%
	Direct Mail Kits	93%
	Direct Mail Kits, Income Qualified	95%
	Community Distributed Kits	95%
Food Bank / Pantry Distribution		98%

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1231] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1232]

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 [1233]
Multifamily in unit	1.04 [1234]
Exterior or uncooled location	1.0
Unknown location	1.051[1235]

measure are so minimal, for ease of implementation the 3 year installs are discounted using the real discount rate to a single assumption.

1231 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.

1232 Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY8 for Ameren.

1233 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)

1234 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)

1235 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.

StandbykWh = Standby power draw of the controlled lamp. Use actual value from manufacturer specification. If not known then assume:

= 0.63 kWh[1236]

For example, a 9W Connected LED is purchased through a ComEd upstream program.

$\Delta kWh_{1st\ year\ installs}$ = (((9/1000) * 1,089 * 0.37 * 1.051) – 0.63) * 0.9 * (1 – 0.008)

= 2.84 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

= 0.37[1237]

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

Bulb Location	WHFd
Interior single family	1.11[1238]
Multifamily in unit	1.07[1239]
Exterior or uncooled location	1.0
Unknown location	1.093[1240]

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF
Interior	0.128[1241]
Exterior	0.273[1242]
Unknown	0.135[1243]

[1236] Based on Lockheed Martin, 'Home Energy Management System/Cmart Lighting Pilot for National Grid's Massachusetts and Rhode Island Residential Energy Efficiency Programs', Final Report, March 18, 2019.

[1237] Assumed equal to SVGe.

[1238] 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.

[1239] 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)

[1240] 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.

[1241] 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.

[1242] 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.

[1243] 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) * 0.37 * 1.093)) * 0.9 * (1 – 0.008)

= 0.0032 kW

FOSSIL FUEL SAVINGS

NA

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

NA

DEEMED O&M COST ADJUSTMENT CALCULATION

NA

MEASURE CODE: RS-LTG-LEDC-V02-230101

REVIEW DEADLINE: 1/1/2026

5.5.13 EISA Exempt LED Lighting

DESCRIPTION

This characterization provides savings assumptions for LED lamps and fixture types that are exempt from the EISA legislation. 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.[1244]

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 or equivalent to the most recent version of ENERGY STAR specifications or be listed on the Design Lights Consortium Qualifying Product List. Note a new ENERGY STAR specification v2.1 became effective on 1/2/2017.

DEFINITION OF BASELINE EQUIPMENT

This measure is only for lamp and fixture types that are exempt from EISA, including lamps with an initial lumen output of less than 310 lumens, with initial lumen output greater than 3,300 lumens, and Task/Undercabinet Fixtures with a linear fluorescent baseline.

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.[1245] 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.[1246]

The rated life of linear task and under cabinet fixtures is 45,000 hours[1247] and for T-LEDS is 50,000 hours. However, all fixture lifetimes are capped at 15 years.[1248]

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:

Type	Incremental Cost
A-Lamps	$1.45[1249]

[1244] 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'.

[1245] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

[1246] Representing a third of the expected lamp lifetime.

[1247] Average rated lives are based on the average rated lives of fixtures available on the ENERGY STAR qualifying list as of 2/26/2018.

[1248] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

[1249] 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.

Type	Incremental Cost
Linear Task/Under Cabinet	$18[1250]
T-LEDs	$13[1251]

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,[1252] 0.273 for exterior bulbs,[1253] and 0.135 for unknown,[1254]

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:[1255]

LED New and Baseline Assumptions Table

[1250] Incremental costs for task/under cabinet and downlight fixtures are from the 2018 Michigan Energy Measures Database.
[1251] Consistent with measure 4.5.4 LED Bulbs and Fixtures in Volume 2.
[1252] 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.
[1253] 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.
[1254]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.
[1255] 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.

Type	Minimum Lumens	Maximum Lumens	LED Wattage (WattsEE)	Baseline (WattsBase)	Delta Watts
A-Lamps	120	310	4.0	25	21.0
	3,300	3,999	28.9	200	171.1
	4,000	5,000	35.7	300	264.3
Linear Task/Under Cabinet	All		11.6	45.2	33.6
T-LEDs	0	1,199	8.9	15	6.1
	1,200	2,399	15.8	28.2	12.4
	2,400		22.9	41.8	18.9

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

Program		In Service Rate (ISR)[1256]s
Retail (Time of Sale)		97.9%[1257]
Direct Install		94.5%[1258]
Virtual Assessment followed by Unverified Self-Install		97.9%[1259]
Efficiency Kits[1260]	LED Distribution[1261]	82.8%
	School Kits[1262]	83.8%

[1256] In Service Rates now represent the lifetime In Service Rates with the second and third year installations discounted by the Real Discount Rate of 0.46%. Lifetime 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. For all other programs Tthe 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.

[1257] 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).

[1258] 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.

[1259] An equal weighted average of Direct Install and Direct Mail Kit ISRs. Interest and applicability of measures confirmed through virtual assessment.

[1260] 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.

[1261] Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

[1262] 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.

Program		In Service Rate (ISR)[1256]s
	Direct Mail Kits[1263]	91.8%
	Direct Mail Kits, Income Qualified[1264]	60%
	Community Distributed Kits[1265]	95.0%
Food Bank / Pantry Distribution[1266]		97.9%[1267]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[1268] of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[1269]

ComEd: 0.8%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

Type	Installation Location	Hours
A-Lamps	Residential and in-unit Multi Family	1,089[1270]
	Exterior	2,475[1271]
	Unknown	1,159[1272]
Linear Task/Under Cabinet	All	730[1273]
T-LEDs	All	730[1274]

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

1263 Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

1264 Research from 2021 Ameren Illinois Income Qualified participant survey (customer self-report), available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf

1265 Kits distributed in a community setting, targeted to income qualified communities. Research from 2018 Ameren Illinois Income Qualified participant survey.

1266 Free bulbs provided through local food banks and food pantries.

1267 1st year ISR is determined based on online surveys conducted for ComEd CY2018 Food Bank LED Distribution program. See 'CY2018 ComEd Foodbank LED Dist Survey Results_Navigant'.

1268 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.

1269 Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY8 for Ameren.

1270 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.

1271 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.

1272 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.

1273 Task/under cabinet hours of use are estimated at 2 hours per day.

1274 Consistent with Linear Task/Under Cabinet assumption.

Bulb Location	WHFe
Interior single family	1.06 [1275]
Multifamily in unit	1.04 [1276]
Exterior or uncooled location	1.0
Unknown location	1.051[1277]

For example, an 4W LED lamp, 300 lumens, is installed in the interior of a home. The customer purchased the lamp through a ComEd upstream program:

ΔkWh = ((25.0 - 4) /1000) * 0.784 * (1 - 0.008) * 1,089 * 1.06

= 18.9 kWh

HEATING PENALTY

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

ΔkWh[1278] = - (((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[1279]

= 0% for exterior or unheated location

= 42% for unknown location[1280]

ηHeat = Efficiency in COP of Heating equipment

[1275] 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)

[1276] 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)

[1277] 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.

[1278] Negative value because this is an increase in heating consumption due to the efficient lighting.

[1279] 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.

[1280] 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.

= actual. If not available use:[1281]

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[1282]	N/A	N/A	1.28

For example: using the same 4W LED that is installed in home with 2.0 COP Heat Pump (including duct loss) through a ComEd upstream program:

$\Delta kWh_{1st\ year}$ = - (((25 - 4) / 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.

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[1283]
Multifamily in unit	1.07[1284]
Exterior or uncooled location	1.0
Unknown location	1.093[1285]

CF = Summer Peak Coincidence Factor for measure.

[1281] 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.

[1282] 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.

[1283] 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.

[1284] 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)

[1285] 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.

Bulb Location	CF
Interior	0.128[1286]
Exterior	0.273[1287]
Unknown	0.135[1288]

Other factors as defined above

For example: for the same 4W LED that is installed in a single family interior location through a ComEd upstream program:

ΔkW = ((25 - 4) / 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.

FOSSIL FUEL 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[1289]

= 0% for exterior location

= 42% for unknown location[1290]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1291]

[1286] 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.

[1287] 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.

[1288] 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.

[1289] Average result from REMRate modeling of several different configurations and IL locations of homes

[1290] 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.

[1291] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

For A-lamps, the baseline lamp is assumed to need replacing after 1000 hours. Therefore a baseline cost of $1.25 should be applied every 0.92 years for interior applications, 0.40 years for exterior applications and 0.86 years for unknown.

For Linear Task/Under Cabinet and T-LEDs, with a linear fluorescent baseline, there is assumed no O&M impact since the baseline lamp life is 18,000 – 30,000 hours and which is longer than the assumed measure life.

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-LEDE-V1-230101

REVIEW DEADLINE: 1/1/2024

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.[1292]

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.[1293] 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

[1292] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[1293] 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%[1294]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1295]

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

= 46.6%[1296]

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_heatingFurnace

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:[1297]

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

1294 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1295 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)'.

1296 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.

1297 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:[1298]

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 [1299]

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,[1300] or if unknown assume the following:[1301]

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[1302]

1298 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

1299 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.

1300 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).

1301 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.

1302 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[1303]

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% [1304]

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[1305]	66%

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

= [(((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

1303 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.

1304 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.

1305 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:[1306]

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:[1307]

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 heat efficiency * distribution efficiency (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,[1308] or if not available refer to default table below.[1309] If actual Distribution Efficiency is not available, use 85% for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate * Distribution Efficiency) = (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	N/A	N/A	1.28

[1306] 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".
[1307] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.
[1308] 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).
[1309] 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 * Distribution Efficiency) = (HSPF/3.413)*0.85
evaluation only)[1310]			

3412 = Converts Btu to kWh

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Fossil Fuels

= If unknown[1311], 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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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

1310 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.

1311 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.

ΔkWh_heatingFurnace = If fossil fuel *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3 * $ADJ_{AirSealingHeatFan}$

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

= 3.14%[1312]

29.3 = kWh per therm

$ADJ_{AirSealingHeatFan}$ = Adjustment for fan savings during heating season to account for inaccuracies in engineering algorithms[1313]

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 Fossil Fuel Savings section):

ΔkWh_heatingGas = 76.3 * 0.0314 * 29.3 * 107%

= 75.1 kWh

***Methodology 2: Prescriptive Infiltration Reduction Measures*[1314]**

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

HEATING SAVINGS

ΔkWh_heating = ($ΔkWh_{gasket}$ * n_{gasket} + $ΔkWh_{windows}$ * $sf_{windows}$ + $ΔkWh_{sweep}$ * n_{sweep} + $ΔkWh_{sealing}$ * $lf_{sealing}$ + $ΔkWh_{WX}$ * lf_{WX}) * $ADJ_{RxAirsealing}$ * ISR

Where:

$ΔkWh_{gasket}$ = Annual kWh savings from installation of air sealing gasket on an electric outlet

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1312 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.

1313 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.

1314 Prescriptive savings are based upon “Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps).” Middletown, CT: KEMA, 2010. Accessed July 30, 2015, and adjusted for relative HDD of Bridgeport/Hartford CT with the IL climate zones. See ‘Rx Airsealing HDD adjustment.xls’ for more information.

Climate Zone (City based upon)	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

n_{gasket} = Number of gaskets installed

$\Delta kWh_{windows}$ = Annual kWh savings from installation of Shrink-Fit Window Kit[1315]

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

1315 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.

Climate Zone (City based upon)	ΔkWh_{WX} / ft	
	Electric Resistance	Heat Pump
2 (Chicago)	13.0	6.5
3 (Springfield)	11.3	5.6
4 (Belleville)	9.0	4.5
5 (Marion)	9.2	4.6

lf_{WX} = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[1316]

= 80%

ISR = In service rate of weatherization kits dependant on install method as listed in table below.[1317]

Selection	ISR
Distributed School Weatherization Kits	0.58[1318]
Distributed Self-Install Income-Qualified Kits[1319]	
Weatherstripping	0.63
Outlet and Switch Gaskets	0.40[1320]
Window Kit	0.57
Door sweep	0.41[1321]
Other Distributed Self-Install Income-Qualified Measures	0.47[1322]
Opt-in Weatherization Kits	
V-seal weatherstripping	0.57
Cell foam tape weatherstripping	0.62
Rope Caulk	0.44
Switch and outlet gaskets	0.60
Door sweep	0.56
Other Self-Install Weatherization Measures	0.56[1323]
Direct Install, Retail	1.0

COOLING SAVINGS

$\Delta kWh = \Delta kWh\_cooling$

1316 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.

1317 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.

1318 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.

1319 Guidehouse. Income Eligible Gas Kits ISR Special Study Results. June 16, 2020.

1320 Research from 2021 Ameren Illinois Income Qualified participant survey, available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf

1321 Research from 2021 Ameren Illinois Income Qualified participant survey, available on IL SAG website: https://ilsag.s3.amazonaws.com/AIC-Income-Qualified-Initiative-Participant-Survey-Results-Memo-FINAL-2022-02-01.pdf

1322 Straight average of other measures.

1323 Guidehouse survey research for Nicor Gas, July 14, 2021.

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

Typical Reductions in Leakage[1324]

Technology	Application	ΔCFM50[1325]
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:[1326]

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

1324 ASHRAE, 2001 AHSRAE Handbook – Fundamentals, Chapter 26, Table 1. Effective Air Leakage Areas (Low-Rise Residential Applications Only).

1325 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

1326 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.

Climate Zone (City based upon)	Single Family	Multifamily
5 (Marion)	903	820
Weighted Average[1327]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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%[1328]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72% [1329]

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

= 46.6% [1330]

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

FOSSIL FUEL SAVINGS

Methodology 1: Blower Door Test

Required methodology when blower door testing is conducted.

If Fossil Fuel heating:

$\Delta Therms = (((CFM50\_existing - CFM50\_new)/N\_heat) * 60 * 24 * HDD * 0.018) / (\eta Heat * 100{,}000) * ADJ_{AirSealingFossilHeat} * IE_{NetCorrection} * \%FossilHeat$

Where:

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

1327 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

1328 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1329 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)'.

1330 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.

= Based on climate zone and building height:[1331]

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:[1332]

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).[1333] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1334] or if Equipment Efficiency is not available, use Section 5.3 to select the appropriate equipment efficiency for the project. If actual Distribution Efficiency is not available, use 85%.

$ADJ_{AirSealingFossilHeat}$ = Adjustment for fossil heating savings to account for inaccuracies in engineering algorithms:[1335]

[1331] 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".

[1332] 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..

[1333] 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.

[1334] 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).

[1335] 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.

Measure	$ADJ_{AirSealingFossilHeat}$
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%[1336]

%FossilHeat = Percent of homes that have fossil fuel space heating

= 100 % for Fossil Fuel heating

= 0 % for Electric Resistance or Heat Pump

= If unknown[1337], use the following table, assuming natural gas heat:

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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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

1336 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.

1337 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.

Methodology 2: Prescriptive Infiltration Reduction Measures[1338]

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 Fossil Heat
1 (Rockford)	0.49
2 (Chicago)	0.47
3 (Springfield)	0.41
4 (Belleville)	0.33
5 (Marion)	0.33

n_{gasket} = Number of gaskets installed

$\Delta therms_{windows}$ = Annual therm savings from installation of Shrink-Fit Window Kit:[1339]

Climate Zone (City based upon)	$\Delta therms_{windows}$ / sf Fossil 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 Fossil 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

[1338] 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.

[1339] 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.

Climate Zone (City based upon)	$\Delta therms_{sealing}$ / ft Fossil 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 Fossil Heat
1 (Rockford)	0.63
2 (Chicago)	0.61
3 (Springfield)	0.53
4 (Belleville)	0.42
5 (Marion)	0.43

lf_{WX} = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[1340]

= 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
	Gas Furnace 80% AFUE * 0.85	68% AFUE
	Oil Furnace 83% AFUE * 0.85	71% AFUE
	Gas Boiler	84% AFUE
	Oil Boiler	86% AFUE

1340 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.

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.[1341] 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-V12-230101

REVIEW DEADLINE: 1/1/2024

[1341] 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.[1342]

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.[1343] 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.

[1342] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1343] 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%[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 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_heatingFurnace)

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.[1347]

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[1348]

24 = Converts hours to days

CDD = Cooling Degree Days

1344 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1345 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 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.

1347 ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991.

1348 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:[1349]

Climate Zone (City based upon)	Conditioned CDD 65	Unconditioned CDD 65[1350]
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[1351]	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 [1352]

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,[1353] or if unknown assume the following:[1354]

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[1355]

= 80%

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%

[1349] 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.

[1350] 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.

[1351] Weighted based on number of occupied residential housing units in each zone.

[1352] 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.

[1353] 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).

[1354] 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.

[1355] 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)[1356]	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)[1357]

= 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:[1358]

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[1359]	4,860	2,895

1356 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

1357 Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

1358 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.

1359 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). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1360] or if not available refer to default table below.[1361] If actual Distribution Efficiency is not available, use 85% for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate * Distribution Efficiency) (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)[1362]	N/A	N/A	1.28

$ADJ_{BasementHeat}$ = Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[1363]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Fossil fuel heating

= If unknown[1364], use the following table:

1360 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).

1361 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.

1362 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).

1362 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 o
ver time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.
. TAC negotiated adjustment factor is 60%.

1364 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%**

__Note__: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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_heatingFurnace = If fossil fuel *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%[1365]

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 Fossil Fuel Savings section :

= 78.3 * 0.0314 * 29.3

= 72.0 kWh

SUMMER COINCIDENT PEAK DEMAND

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

[1365] 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

= dependent on location:[1366]

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[1367]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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% [1368]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72% [1369]

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

= 46.6% [1370]

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

FOSSIL FUEL SAVINGS

If Fossil Fuel 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-

1366 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.

1367 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

1368 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1369 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)'.

1370 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.

Framing_factor))) * 24 * HDD) / (ηHeat * 100,000)) * $ADJ_{BasementHeat}$ * %FossilHeat

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= 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,[1371] or if unknown assume 72% for existing system efficiency[1372]. If actual Distribution Efficiency is not available, use 85%.

%FossilHeat = Percent of homes that have fossil fuel space heating

= 100 % for Fossil Fuel heating

= 0 % for Electric Resistance or Heat Pump

= If unknown[1373], use the following table, assuming natural gas heat:

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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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

1371 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).

1372 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

1373 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.

Efficiency Assumption	System Type	New Baseline Efficiency
	Heat Pump	14 SEER
ηHeat	Electric Resistance	1.0 COP
	Heat Pump (8.2HSPF/3.413)*0.85	2.04 COP
	Gas Furnace 80% AFUE * 0.85	68% AFUE
	Oil Furnace 83% AFUE * 0.85	71% AFUE
	Gas Boiler	84% AFUE
	Oil Boiler	86% 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.[1374] 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-V13-230101

REVIEW DEADLINE: 1/1/2025

[1374] 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.[1375]

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.[1376] 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

[1375] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1376] 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%[1377]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1378]

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

= 46.6%[1379]

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_heatingFurnace)

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 [1380]

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% [1381]

24 = Converts hours to days

CDD = Cooling Degree Days

[1377] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1378] 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)'.

[1379] 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.

[1380] 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

[1381] 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[1382]
1 (Rockford)	263
2 (Chicago)	281
3 (Springfield)	436
4 (Belleville)	538
5 (Marion)	570
Weighted Average[1383]	325

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

= 0.75 [1384]

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,[1385] or if unknown assume the following:[1386]

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[1387]

= 80%

%Cool = Percent of homes that have cooling

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

[1382] 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.

[1383] Weighted based on number of occupied residential housing units in each zone.

[1384] Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[1385] 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).

[1386] 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.

[1387] 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)[1388]	

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:[1389]

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[1390]	2,895

ηHeat = Efficiency of heating system

= Actual Heating Efficiency * Distribution Efficiency (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,[1391] or if not available refer to default table below.[1392] If actual Distribution Efficiency is not available, use 85%.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate * Distribution Efficiency) (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

1388 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

1389 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.

1390 Weighted based on number of occupied residential housing units in each zone.

1391 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).

1392 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.

only)[1393]			

$ADJ_{FloorHeat}$ = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings[1394]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Fossil Fuel heating

= If unknown[1395], 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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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_heatingFurnace = If fossil fuel *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

1393 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.

1394 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%.

1395 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%[1396]

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 Fossil Fuel 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:[1397]

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[1398]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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%[1399]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1400]

1396 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.

1397 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.

1398 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

1399 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1400 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

= 46.6%[1401]

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

FOSSIL FUEL SAVINGS

If Fossil Fuel heating:

ΔTherms = (((1/R_old - 1/(R_added+R_old)) * Area * (1-Framing_factor) * 24 * HDD) / (100,000 * ηHeat)) * $ADJ_{FloorHeat}$ * %FossilHeat

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= 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,[1402] or if unknown assume 72% for existing system efficiency.[1403] If actual Distribution Efficiency is not available, use 85%.

%FossilHeat = Percent of homes that have fossil fuel space heating

= 100 % for Fossil Fuel heating

= 0 % for Electric Resistance or Heat Pump

= If unknown[1404], use the following table, assuming natural gas heat:

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%

1401 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.

1402 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).

1403 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

1404 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					**76%**

<u>Note</u>: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

Other factors as defined above.

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 72% efficient furnace:

ΔTherms = ((1 / 3.53 – 1 /(30 + 3.53))*(20 * 25) * (1 - 0.12) * 24 * 3079) / (100,000 * 0.72) * 0.60 * 1

= 68.7 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
	Gas Furnace 80% AFUE * 0.85	68% AFUE
	Oil Furnace 83% AFUE * 0.85	71% AFUE
	Gas Boiler	84% AFUE
	Oil Boiler	86% 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.[1405] 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

[1405] 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-FINS-V14-230101

REVIEW DEADLINE: 1/1/2025

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.[1406]

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.[1407] 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%[1408]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

[1406] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1407] 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.

[1408] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 72%[1409]

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

= 46.6%[1410]

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_heatingFurnace

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)[1411]

A_wall = Net area of insulated wall (ft^2)

Framing_factor_wall = Adjustment to account for area of framing

= 25%[1412]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1413]

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

1409 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)'.
1410 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.
1411 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).
1412 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1
1413 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[1414]	

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

= 0.75 [1415]

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,[1416] or if unknown assume the following:[1417]

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[1418]

= 80%

%Cool = Percent of homes that have cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[1419]	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

1414 Weighted based on number of occupied residential housing units in each zone.

1415 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.

1416 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).

1417 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.

1418 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%.

1419 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:[1420]

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[1421]	4,860

ηHeat = Efficiency of heating system

= Actual Heating Efficiency * Distribution Efficiency (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,[1422] or if not available refer to default table below.[1423] If actual Distribution Efficiency is not available, use 85% for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate * Distribution Efficiency) (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)[1424]	N/A	N/A	1.28

3412 = Converts Btu to kWh

$ADJ_{WallHeat}$ = Adjustment for heating savings to account for inaccuracies in prescriptive engineering

[1420] 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.

[1421] Weighted based on number of occupied residential housing units in each zone.

[1422] 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).

[1423] 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.

[1424] 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).

[1424] 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 o algorithms.[1425]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Fossil Fuel heating

= If unknown[1426], 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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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_heatingFurnace = If fossil fuel *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%[1427]

ver time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

. TAC negotiated adjustment factor is 60%.

[1426] 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.

[1427] 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.

29.3 = kWh per therm

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11 with a gas furnace with system efficiency of 66% (for therm calculation see Fossil Fuel 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:[1428]

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[1429]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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%[1430]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%[1431]

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

= 46.6%[1432]

[1428] 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.

[1429] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

[1430] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1431] 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)'.

[1432] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11, 10.5 SEER Central AC, and 2.26 COP Heat Pump:

ΔkW_{SSP} = 93.5 / 570 * 0.68

= 0.11 kW

ΔkW_{PJM} = 93.5 / 570 * 0.466

= 0.08 kW

FOSSIL FUEL SAVINGS

If Fossil Fuel heating:

ΔTherms = (((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall) * 24 * HDD) / (ηHeat * 100,000 Btu/therm)) * $ADJ_{WallHeat}$ * %FossilHeat

Where:

HDD = Heating Degree Days

= Dependent on location:[1433]

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[1434]	4,860

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate).[1435] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1436] or if unknown assume 72% for existing system efficiency.[1437] If actual Distribution Efficiency is not available, use 85%.

%FossilHeat = Percent of homes that have fossil fuel space heating

= 100 % for Fossil Fuel heating

1433 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.

1434 Weighted based on number of occupied residential housing units in each zone.

1435 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.

1436 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).

1437 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

= 0 % for Electric Resistance or Heat Pump

= If unknown[1438], use the following table, assuming natural gas heat:

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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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
	Gas Furnace 80% AFUE * 0.85	68% AFUE
	Oil Furnace 83% AFUE * 0.85	71% AFUE
	Gas Boiler	84% AFUE
	Oil Boiler	86% AFUE

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment,

1438 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.

estimate to be 10 years or 13 years for boilers.[1439] 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-WINS-V12-230101

REVIEW DEADLINE: 1/1/2024

[1439] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

5.6.5 Ceiling/Attic Insulation

Description

Insulation is added to attic. This measure requires a member of the implementation staff evaluating the pre and post R-values and measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

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

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

Definition of Efficient Equipment

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be little or no attic insulation.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[1440]

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.[1441] 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%[1442]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

1440 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

1441 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.

1442 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 72%[1443]

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

= 46.6%[1444]

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_heatingFurnace)

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)[1445]

A_attic = Total area of insulated ceiling/attic (ft^2)

Framing_factor_attic = Adjustment to account for area of framing

= 7%[1446]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1447]

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[1448]	947

[1443] 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)'.
[1444] 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.
[1445] 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.
[1446] Ibid.
[1447] 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.
[1448] 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 [1449]

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,[1450] or if unknown assume the following:[1451]

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[1452]

= 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%[1453]

%Cool = Percent of homes that have cooling

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

[1449] 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.

[1450] 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).

[1451] 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.

[1452] 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.

[1453] 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)[1454]	

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:[1455]

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[1456]	4,860

ηHeat = Efficiency of heating system

= Actual Heating Efficiency * Distribution Efficiency (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,[1457] or if not available refer to default table below.[1458] If actual Distribution Efficiency is not available, use 85% for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate * Distribution Efficiency)= (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

1454 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

1455 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.

1456 Weighted based on number of occupied residential housing units in each zone.

1457 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).

1458 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 * Distribution Efficiency)= (HSPF/3.413)*0.85
only)[1459]			

3412 = Converts Btu to kWh

$ADJ_{AtticElectricHeat}$ = Adjustment for electric heating savings to account for inaccuracies in engineering algorithms[1460]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Fossil Fuel heat

= If unknown[1461], 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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

1459 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.

1460 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.

1461 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_heatingFurnace = If fossil fuel *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%[1462]

29.3 = kWh per therm

$ADJ_{AtticHeatFan}$ = Adjustment for fan savings to account for innacuracies in engineering algorithms[1463]

= 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 Fossil Fuel 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:[1464]

1462 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.

1463 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.

1464 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[1465]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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%[1466]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%[1467]

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

= 46.6%[1468]

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

FOSSIL FUEL SAVINGS

If Fossil Fuel heating:

$$\Delta Therms = ((((1/R\_old - 1/R\_attic) * A\_attic * (1-Framing\_factor\_attic)) * 24 * HDD) / (\eta Heat * 100{,}000\ Btu/therm) * ADJ_{AtticGasHeat} * IE_{NetCorrection} * \%FossilHeat$$

Where:

HDD = Heating Degree Days

= Dependent on location:[1469]

[1465] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

[1466] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1467] 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)’.

[1468] 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.

[1469] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the

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[1470]	4,860

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate).[1471] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1472] or if not available, use 72% for existing system efficiency.[1473] If actual Distribution Efficiency is not available, use 85%.

$ADJ_{AtticGasHeat}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms[1474]

= 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% [1475]

%FossilHeat = Percent of homes that have fossil fuel space heating

= 100 % for Fossil fuel heat

= 0 % for Electric Resistance or Heat Pump

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.

1470 Weighted based on number of occupied residential housing units in each zone.

1471 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.

1472 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).

1473 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

1474 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.

1475 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.

= If unknown[1476], use the following table, assuming natural gas heat:

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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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
	Gas Furnace 80% AFUE * 0.85	68% AFUE
	Oil Furnace 83% AFUE * 0.85	71% AFUE
	Gas Boiler	84% AFUE
	Oil Boiler	86% AFUE

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment,

[1476] 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.

estimate to be 10 years or 13 years for boilers.[1477] Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AINS-V06-230101

REVIEW DEADLINE: 1/1/2025

[1477] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

5.6.6 Rim/Band Joist Insulation

Description

This measure describes savings from adding insulation (either rigid or spray foam) to rim/band joist cavities. This measure requires a member of the implementation staff evaluating the pre- and post-project R-values and to measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

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

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

Definition of Efficient Equipment

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities and little or no attic insulation.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[1478]

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[1479]. 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%[1480]

[1478] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1479] 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.

[1480] 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%[1481]

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

= 46.6%[1482]

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_heatingFurnace)

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)[1483]

A_{Rim} = Net area of insulated rim/band joist (ft^2)

$FramingFactor_{Rim}$ = Adjustment to account for area of framing

= 5%[1484]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1485]

[1481] 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)'.

[1482] 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.

[1483] 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).

[1484] 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.

[1485] 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[1486]
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[1487]	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 [1488]

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,[1489] or if unknown assume the following:[1490]

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[1491]

= 80%

%Cool = Percent of homes that have cooling

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

[1486] 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.
[1487] Weighted based on number of occupied residential housing units in each zone.
[1488] 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.
[1489] 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).
[1490] 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.
[1491] 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)[1492]	

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:[1493]

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[1494]	4,860	2,895

ηHeat = Efficiency of heating system

= Actual Heat Efficiency * Distribution Efficiency (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,[1495] or if not available, refer to default table below:[1496] If actual Distribution Efficiency is not available, use 85% for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate * Distribution Efficiency)= (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	N/A	N/A	1.28

[1492] 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

[1493] 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.

[1494] Weighted based on number of occupied residential housing units in each zone.

[1495] 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).

[1496] 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 * Distribution Efficiency)= (HSPF/3.413)*0.85
evaluation only)[1497]			

3412 = Converts Btu to kWh

$ADJ_{BasementHeat}$ = Adjustment for basement wall and rim/band joist insulation to account for prescriptive engineering algorithms overclaiming savings[1498]

= 60%

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Fossil Fuel heat

= If unknown[1499], 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%**

<u>Note</u>: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

1497 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).

1497 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 o

ver time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

. TAC negotiated adjustment factor is 60%.

1499 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 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_heatingFurnace = If fossil fuel *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%[1500]

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 Fossil Fuel 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:[1501]

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[1502] ComEd	567	504

[1500] 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.

[1501] 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.

[1502] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

Climate Zone (City based upon)	Single Family	Multifamily
Ameren	810	734
Statewide	632	565

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%[1503]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%[1504]

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

= 46.6%[1505]

For example, a single family home in Chicago with 100 ft² of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkW_{SSP} = 5.6 / 570 * 0.68

= 0.0067 kW

ΔkW_{PJM} = 5.6 / 570 * 0.466

= 0.0046 kW

FOSSIL FUEL SAVINGS

If Fossil Fuel heating:

$$\Delta Therms = \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJ_{BasementHeat} * \%FossilHeat}{(\eta Heat * 100{,}000)}$$

Where:

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate).[1506] If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time,[1507] or if not available, use 72% for existing system efficiency.[1508] If actual Distribution Efficiency is not available.

%FossilHeat = Percent of homes that have fossil fuel space heating

= 100 % for Fossil Fuel heat

1503 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1504 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)'.

1505 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.

1506 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.

1507 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).

1508 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

= 0 % for Electric Resistance or Heat Pump

= If unknown[1509], use the following table, assuming natural gas heat:

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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

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
	Gas Furnace 80% AFUE * 0.85	68% AFUE
	Oil Furnace 83% AFUE * 0.85	71% AFUE
	Gas Boiler	84% AFUE
	Oil Boiler	86% AFUE

1509 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.[1510] 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-RINS-V05-230101

REVIEW DEADLINE: 1/1/2025

[1510] 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.

5.6.7 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[1511]

Climate Zone	Emissivity	Solar Transmission
1 - Rockford	≤ 0.22	> 0.55
2 - Chicago		
3 - Springfield		
4 - Belleville		Any
5 – Marion		

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.[1512]

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.[1513]

LOADSHAPE

Loadshape R08 - Residential Cooling

[1511] ENERGY STAR Storm Windows Key Product Criteria, accessed February 2020.
[1512] 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.
[1513] 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%[1514]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1515]

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

= 46.6%[1516]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heatingElectric} + \Delta kWh_{heatingFurnace}$$

$$\Delta kWh_{cooling} = CS_{cz} * Area_{window}$$

$$\Delta kWh_{heatingElectric} = EHS_{cz} * Area_{window}$$

$$\Delta kWh_{heatingFurnace} = \Delta Therms * F_e * 29.3$$

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[1517]

[1514] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1515] 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)'.

[1516] 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.

[1517] 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[1518]

	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 fossil fuel heating as calculated below

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption, 3.14%[1519]

29.3 = Conversion factor, kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \mathrm{kW} = \left(\frac{\Delta \mathrm{kWh_{cooling}}}{\mathrm{FLH_{cooling}}}\right) * \mathrm{CF}$$

Where:

[1518] 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).

[1519] 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:[1520]

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
Weighted Average[1521]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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%[1522]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1523]

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

= 46.6%[1524]

FOSSIL FUEL SAVINGS

$$\Delta Therms = GHS_{cz} * Area_{window}$$

Where:

GHS_{cz} = Annual fossil fuel heating savings per area of window by climate zone, see table below

Heating savings per window area by climate zone and baseline window condition[1525]

Climate Zone	Single Pane Base Window (therms/ft^2)	Double Pane Base Window (therms/ft^2)
1 - Rockford	0.80	0.09

1520 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.

1521 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

1522 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1523 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)'.

1524 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.

1525 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

Climate Zone	Single Pane Base Window (therms/ft^2)	Double Pane Base Window (therms/ft^2)
2 - Chicago	0.76	0.09
3 - Springfield	0.65	0.07
4 - Belleville	0.50	0.06
5 - Marion	0.51	0.06

$Area_{window}$ = 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-V02-230101

REVIEW DEADLINE: 1/1/2024

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.

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[1526]

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

[1526] Modeled savings developed by Robert Hart, Berkeley National Lab – "High Performance Windows - Illinois Modeled Savings Summary", April 2021.

Table 2: Illinois Code - Window Values[1527]

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[1528]

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[1529]

Remaining life of existing equipment – 13 years[1530]

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[1531] – $3.13/ft^2

The incremental cost of triple glazed windows accounts for increased material and installation costs.

Thin Triple Pane Windows[1532] - $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)

1527 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

1528 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.

1529 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

1530 Assumed to be one third of effective useful life. For future TRM versions, recommend RUL be informed from program research.

1531 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

1532 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[1533].

Thin Triple Pane Windows[1534] - \$50.80/ft^2

Triple Glazed Windows[1535] – \$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%[1536]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour) = 72%[1537]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period) = 46.6%[1538]

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.

1533 \$37.82 inflated using 1.91% rate.

1534 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

1535 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

1536 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."

1537 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)'."

1538 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[1539]

Climate Zone	New Construction or Time of Sale (kWh/ft²)	Early Replacement (kWh/ft²)
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[1540]

	Electric Resistance Heat + AC		Electric Heat Pump	
Climate Zone	New Construction or Time of Sale (kWh/ft²)	Early Replacement (kWh/ft²)	New Construction or Time of Sale (kWh/ft²)	Early Replacement (kWh/ft²)
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. [1541]

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

1539 EnergyPlus models were used to develop the savings per Hart 2018 paper methods and assumptions, Illinois Savings Summary

1540 Ibid

1541 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."

Weighted Average[1542]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour) = 68%[1543]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour) = 72%[1544]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period) = 46.6%[1545]

FOSSIL FUEL 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

1542 Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

1543 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."

1544 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)'."

1545 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."

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:

$$\Delta Therms = 0.11 * 120 = 13.2 \; therms$$

$$\Delta kWh = 0.55 * 120 = 66 \; kWh$$

$$\Delta kW_{PJM} = \left(\frac{66}{512}\right) * 0.466 = 0.129 \; kW$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-TTWI-V02-230101

REVIEW DEADLINE: 1/1/2024

5.6.9 Insulated Cellular Shades

Description

Insulating cellular shades greatly improve the thermal envelope performance compared to uncovered windows or conventional vinyl window coverings. These coverings have a honeycomb or cellular structure that can be operated manually or automated. Insulated cellular shades are considered to have the highest R-value among available blinds, shades, and other window coverings. They are designed with multiple layers of varying fabrics to trap air inside pockets that act as insulators and increase the R-value of the window covering and reduce the thermal heat transfer through windows.

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. These products provide benefits for both heating and cooling seasons 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: TOS, NC. If applied to other program types, the measure savings should be verified

Definition of Efficient Equipment

The efficient insulating cellular shades must be at least a double cell design installed on at least 75% of a home's windows. The Attachments Energy Rating Council (AERC) has a third party verified rating that has been developed for residential window attachments[1546]. If possible, utilizing the AERC rating system, eligible insulating cellular shades need to have a Cool Climate Rating greater or equal to 10 due to the Illinois climate.

Definition of Baseline Equipment

The baseline for this measure is a home with uncovered windows or standard existing shades or blinds.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 10 years.

Deemed Measure Cost

The costs of window coverings vary greatly based on factors other than energy efficiency. The incremental cost of insulated cellular shades over standard window coverings is assumed to be $40 per shade or $600 per home.

Loadshape

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

Coincidence Factor

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour) = 68% [1547]

[1546] Attachments Energy Rating Council. May 01, 2022. www.https://aercenergyrating.org/

[1547] 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."

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour) = 72% [1548]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period) = 46.6%[1549]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = (\Delta kWh_{\_cooling} + \Delta kWh_{\_heatingElectric} + \Delta kWh_{\_heatingFurnace})$

Where:

$\Delta kWh_{\_Cooling}$ = If central cooling, reduction in annual cooling requirement due to cellular window shades

= FLH_{cool} * Capacity_cooling * ((1/SEER)/1000) * ESF_{cool}

FLH_{cool} = Full load cooling hours

= Dependent on location as below:[1550]

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[1551]		
ComEd	567	504
Ameren	810	734
Statewide	632	565

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

Capacity_cooling = 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

[1548] 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)'."

[1549] 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."

[1550] 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.

[1551] Weighting for Ameren is based on electric accounts in each of the cooling zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

Btu/hr for mobile homes.[1552] If building type is unknown, assume 31,864Btu/hr.[1553]

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,[1554] or:

Cooling System	SEER[1555]
Air Source Heat Pump	12
Central AC	

ESF_{cool} = Insulating cellular shades cooling energy savings factor

= 0.05[1556]

$\Delta kWh_{\_Heating\ Electric}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to cellular window shades

= FLH_{heat} * Capacity_heating * $((1/HSPF_{ASHP})/1000)$ * ESF_{heat}

FLHheat = Full load heating hours

= Dependent on location as below:[1557]

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[1558]	
ComEd	1,846
Ameren	1,612
Statewide	1,821

1552 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.

1553 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.

1554 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).

1555 Estimate based upon Navigant, 2018 "EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case"

1556 Average of HVAC savings for typical use compared to baseline conditions of no shades and common vinyl blinds. "Testing the Performance and Dynamic Control of Energy-Efficient Cellular Shades in the PNNL Lab Homes." PNNL. August 2018. Table 4.3 https://aercnet.org/wp-content/uploads/2018/10/Testing-the-Performance-and-Dynamic-Control-of-Energy-Efficient-Cellular-Shades-in-the-PNNL-Lab-Homes.pdf.

1557 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.

1558 Weighting for Ameren is based on electric heat accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

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

= Actual

$HSPF_{ASHP}$ = Heating Seasonal Performance Factor of efficient Air Source Heat Pump (kBtu/kWh)

= Actual or 8.5 if unknown[1559]

ESF_{heat} = Insulating cellular shades heating energy savings factor

= 0.02[1560]

$\Delta kWh_{\_Heating\ Furnace}$ = If fossil fuel heat, kWh savings for reduction in furnace fan run time

= ΔTherms * F_e * 29.3

ΔTherms = (CAPInputPre ∗ EFLH ∗ (1/ Eff)*ESFheat)) / 100,000

CAPInputPre = Gas Furnace input capacity (Btuh)

= Actual. If unknown, use the table below:

Eligibility Tier	Input Capacity[1561]
AFUE ≥ 95 (all furnaces, no tiers)	84,305

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[1562]	
ComEd	978
Ameren	800
Statewide	928

Eff = Efficiency of furnace

= Actual. If unknown, use 72% for existing system efficiency.[1563]

[1559] ENERGY STAR minimum.

[1560] "Testing the Performance and Dynamic Control of Energy-Efficient Cellular Shades in the PNNL Lab Homes." PNNL. August 2018. https://aercnet.org/wp-content/uploads/2018/10/Testing-the-Performance-and-Dynamic-Control-of-Energy-Efficient-Cellular-Shades-in-the-PNNL-Lab-Homes.pdf.

[1561] 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.

[1562] Weighting for Ameren is based on gas accounts in each of the heating zones. Weighting for ComEd and Statewide average is based on number of occupied residential housing units in each zone. ComEd is weighted average of Zones 1-2. Alternative program-weighted assumptions can be used if appropriate.

[1563] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

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

= 3.14%[1564]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = Capacity\_cooling * ((1/EER)/1000) * ESF_d * CF$$

Where:

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

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

$EER = (-0.02 * SEER\_exist^2) + (1.12 * SEER\_exist)$ [1565]

If SEER or EER rating unavailable, use:

Cooling System	EER[1566]
Air Source Heat Pump	10.5
Central AC	

ESF_d = Insulating cellular shades heating energy savings factor

= 0.02[1567]

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

= 68% [1568]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72% [1569]

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

1564 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.

1565 From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

1566 Based on converting SEER assumption to EER.

1567 “Testing the Performance and Dynamic Control of Energy-Efficient Cellular Shades in the PNNL Lab Homes.” PNNL. August 2018. https://aercnet.org/wp-content/uploads/2018/10/Testing-the-Performance-and-Dynamic-Control-of-Energy-Efficient-Cellular-Shades-in-the-PNNL-Lab-Homes.pdf.

1568 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.”

1569 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)’.”

= 46.6%[1570]

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-INCS-V01-230101

REVIEW DEADLINE: 1/1/2026

[1570] 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."

5.6.10 Multifamily Whole Building Aerosol Sealing

DESCRIPTION

Multifamily buildings have many of the same leakage paths as single-family homes, as well as additional paths hidden in shared walls or other cavities that are difficult to seal with conventional methods. Typically, shared walls between multifamily homes are difficult to air seal effectively, leading to issues when trying to meet code. This measure is the application of an aerosol sealant to a new or existing multifamily building. The aerosol envelope sealing technology uses an automated approach to produce extremely tight envelopes.

Air is blown into a multifamily unit while an aerosol sealant "fog" is released in the interior. As air escapes the building through leaks in the envelope, the sealant particles are carried to the leaks where they impact and stick to the edges of the leaks, eventually sealing them. A standard house or duct air leakage test fan is used to pressurize the building and provide real-time feedback and a permanent record of the sealing. The process is more effective and convenient than conventional sealing methods because it requires less time and effort, it can seal a larger portion of a leakage area more quickly, and can be used to meet more stringent compartmentalization requirements. It can be used to seal multiple units in a residential multi-family building in a cost-effective manner. Energy savings are estimated using EnergyPlus whole-building energy simulations.

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

DEFINITION OF EFFICIENT EQUIPMENT

Existing multifamily units which have been aerosol sealed that meet an air exchange rate of 3.0 ACH50 (air changes per hour) or lower. This meets the residential energy code tightness requirements[1571]. New multifamily units which have been aerosol sealed that meet an air exchange rate of 0.6 ACH50 (air changes per hour) or lower. This meets the Passive House tightness requirements.[1572]

DEFINITION OF BASELINE EQUIPMENT

Existing multifamily buildings that are undergoing a major envelope retrofit. The existing air leakage should be determined through approved and appropriate test methods using a blower door at 50 Pascals. Note that setting up a blower door is a required step in the aerosol sealing process.

The baseline for new construction buildings would be the applicable code for air exchange rate.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1573]

DEEMED MEASURE COST

The measure cost for this aerosol sealing technology is $0.50/sq.ft. of home size[1574].

LOADSHAPE

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

[1571] ICC. 2018 International Energy Conservation Code, International Code Council, Inc
ICC. 2018 International Residential Code, International Code Council, Inc.

[1572] PHI (Passive House Institute). 2016. Passive House requirements (http://passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm). Information accessed on April 2022

[1573] Center for Energy and Environment. Demonstrating the Effectiveness of an Aerosol Sealant to Reduce Multi-Unit Dwelling Envelope Air Leakage. December 30, 2016. http://mn.gov/commerce-stat/pdfs/card-cee-aerosol.pdf#page=47&zoom=100,0,404

[1574] Ibid

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

Energy savings are estimated using EnergyPlus whole-building energy simulations.

It is important to note that the energy savings for multifamily whole-building sealing process cannot be estimated using a simple infiltration algorithm. This is because conversion of the measured building leakage (ACH50) to infiltration at natural conditions treats the entire building as a single zone and does not account for air movement between zones and housing units and also does not consider effects of mechanical ventilation. Therefore, whole building level energy modeling must be done to estimate energy savings.

Baseline and efficient energy models were developed in the referenced study for Minneapolis climate zone.[1575] The energy savings in this measure have been adjusted for the Illinois climate zones based on degree days.[1576] A multifamily building with six floors was modeled containing four housing units in each floor. Each modeled unit is 30 ft wide and 40 ft long with a floor area of 1,200 ft^2. The floor plan is the same for each of the six floors in the modeled building and is symmetric to minimize the effects of building orientation on the simulation results.

The heating system consists of a central boiler that served each apartment through terminal units. The boiler system is rated for 75% seasonal efficiency. Cooling is provided by window air conditioners. The independent variables include the building's physical characteristics and operating parameters of the ventilation systems. The dependent variables include building energy use, total outside air flow (e.g. infiltration and ventilation), and inter-zonal air flows (e.g. adjoining units and units to/from common spaces).

ELECTRIC ENERGY SAVINGS

There is minimal impact on the cooling energy savings.[1577] There is a slight increase in the cooling energy needed after sealing due to less infiltration to offset internal loads. Due to the relatively small impact on cooling, it is not considered to be significant.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

The natural gas space heating savings are dependent on the ventilation system and whether the multifamily unit is existing or new construction.

Four types of continuous ventilation schemes were modeled for the apartments.

a) Exhaust Only: Exhaust fan in each unit with no direct supply of outdoor air. Consists of a single fan connected to a centrally located, single exhaust point in the house.
b) Exhaust and Half Supply: Ventilation scheme having both exhaust and supply ventilation systems. Full capacity exhaust fan in each unit with supply ventilation to the unit that is approximately half the exhaust capacity.
c) Balanced: A balanced ventilation system that has two fans and two duct systems. They introduce and exhaust approximately equal quantities of fresh outside air and polluted inside air.

1575 Center for Energy and Environment. Demonstrating the Effectiveness of an Aerosol Sealant to Reduce Multi-Unit Dwelling Envelope Air Leakage. December 30, 2016. http://mn.gov/commerce-stat/pdfs/card-cee-aerosol.pdf#page=47&zoom=100,0,404

1576 "Whole Home Sealing HDD Adjustment Spreadsheet.xlsx"

1577 "Whole Home Sealing HDD Adjustment Spreadsheet.xlsx". The cooling savings penalties are extremely small in the order of 1-3% of the heating savings and have been excluded from this analysis.

d) No Ventilation: No continuous or intermittent mechanical ventilation. This is the most common type of ventilation scheme in existing multifamily buildings.

Natural Gas savings for each ventilation type normalized per multifamily unit are listed in the below tables by climate zone. The air exchange rate baseline for the New Building energy simulations was 3.0ACH50 and the measure case was 0.6ACH50; whereas the baseline for the existing building energy simulations was 9.5ACH50 and the measure case was 3.0ACH50[1578].

Climate Zone (City based upon)	New Building Space Heating Savings (therms/unit)			
	Exhaust	Exhaust and half supply	Balanced	No ventilation
1 (Rockford)	10.3	14.6	23.2	22.3
2 (Chicago)	9.9	14.1	22.4	21.5
3 (Springfield)	8.6	12.2	19.4	18.7
4 (Belleville)	6.9	9.7	15.5	14.9
5 (Marion)	7.0	9.9	15.8	15.2

Climate Zone (City based upon)	Existing Building Space Heating Savings (therms/unit)			
	Exhaust	Exhaust and half supply	Balanced	No ventilation
1 (Rockford)	35.2	48.1	57.5	58.4
2 (Chicago)	34.0	46.4	55.5	56.3
3 (Springfield)	29.5	40.2	48.1	48.9
4 (Belleville)	23.5	32.1	38.3	38.9
5 (Marion)	24.0	32.8	39.2	39.8

$$\Delta Therms/unit = Therms_{ModeledSavings} \times\ Heating\ Efficiency_{Correction\ Factor} \times Volume_{Correction\ Factor}$$

Where:

$Therms_{ModeledSavings}$ = From above tables depending on the building vintage, climate zone and ventilation system

$HeatingEfficiency_{CorrectionFactor}$ = $HeatingEfficiency_{Modeled}/HeatingEfficiency_{Actual}$

where, $HeatingEfficiency_{Modeled}$ is 0.75

and $HeatingEfficiency_{Actual}$ is the efficiency of the actual heating system. If unknown, use a correction factor of 1 for existing buildings and the applicable code baseline efficiency for new buildings.

1578 Center for Energy and Environment. Demonstrating the Effectiveness of an Aerosol Sealant to Reduce Multi-Unit Dwelling Envelope Air Leakage. pp 76, 79. December 30, 2016. http://mn.gov/commerce-stat/pdfs/card-cee-aerosol.pdf#page=47&zoom=100,0,404

$Volume_{CorrectionFactor}$ = $Volume_{Actual}/Volume_{Modeled}$

where, $Volume_{Modeled}$ is 12,000 ft^3

and $Volume_{Actual}$ is the volume of the actual unit.

If unknown, use a correction factor of 1.

For example, An existing 1,000 sq.ft. multi-family unit with 10 ft. ceilings, 80% efficiency central boiler in a 6-unit building in Chicago with no dedicated ventilation is sealed using whole home aerosol sealing technique. The annual natural gas savings for the measure from the table would be -

ΔTherms = 56.3 x (0.75/0.80) x (10,000/12,000)

= 43.9 therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AERO-V01-230101

REVIEW DEADLINE: 1/1/2026

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%.[1579]

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:

[1579] 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.[1580]

DEEMED MEASURE COST

For TOS and NC, the incremental costs for ENERGY STAR in-ground pool pumps are estimated as $314[1581] and for above ground pool pumps are estimated as $930.[1582]

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.[1583]

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS[1584]

For TOS and NC:

$$\Delta kWh = (Gallons * Turnovers * (1/WEF_{base} - 1/WEF_{ESTAR}) * Days) / 1000$$

For Early Replacement:

$$\Delta kWh = (Gallons * Turnovers * (1/EF_{Exist} - 1/WEF_{ESTAR}) * Days) / 1000$$

[1580] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[1581] ENERGY STAR Pool Pump Calculator and represent the difference between the two/multi speed incremental cost and the variable speed incremental cost.
[1582] 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.
[1583] Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.
[1584] 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[1585]
Above ground	7,540[1586]

Turnovers = Desired number of pool water turnovers per day

= 2[1587]

WEF_{base} = Weighted Energy Factor of baseline pump (gal/Wh) [1588]

Pool Type	WEF_{Base}
In ground	4.63
Above ground	2.57

WEF_{ESTAR} = Weighted Energy Factor of ENERGY STAR pump (gal/Wh) [1589]

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[1590]

Days = Number of days per year that the swimming pool is operational

= 122[1591]

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

1585 Consistent with assumption in the 2020 ENERGY STAR calculator.

1586 Based on typical pool sizes from “Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains, The California Urban Water Conservation Council”, 2010.

1587 Consistent with assumption in the 2020 ENERGY STAR calculator.

1588 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.

1589 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.

1590 Consistent with assumption in the 2020 ENERGY STAR calculator, assuming 1.5 HP pump.

1591 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:

ΔkW = $((kWh/day_{base})/(Hrs/day_{base}) – (kWh/day_{ESTAR})/(Hr/day_{ESTAR}))$ * CF

For Early Replacement:

ΔkW = $((kWh/day_{Exist})/(Hrs/day_{Exist}) – (kWh/day_{ESTAR})/(Hr/day_{ESTAR}))$ * 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[1592]	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[1593]

Based on defaults provided above:

[1592] 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'.

[1593] 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%

FOSSIL FUEL 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.[1594]

DEEMED MEASURE COST

The incremental costs for both are $0.[1595]

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[1596]

[1594] 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.

[1595] 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."

[1596] 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

FOSSIL FUEL 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[1597]

GPF_{Eff} = Efficient equipment gallons per flush

= 1.28 for toilets[1598]

NFPD = Number of flushes per day per occupant

= 5 [1599]

Household = Number of people in the houshold.

= Actual. If unknown assume average number of people per household:

Household Unit Type[1600]	Household
Single-Family - Deemed	2.56[1601]
Multi-Family - Deemed	2.1[1602]
Household type unknown	2.42[1603]
Custom	Actual Occupancy or Number of Bedrooms[1604]

Use Multifamily if: Building meets utility's definition for multifamily

ADPY = Annual days per year

[1597] U. S. EPA WaterSense. "Water Efficiency Management Guide – Bathroom Suite" (EPA 832-F-17-016d), Nov 2017.
[1598] U. S. EPA WaterSense. "Water Efficiency Management Guide – Bathroom Suite" (EPA 832-F-17-016d), Nov 2017.
[1599] U.S. EPA WaterSense, "Water Specification for Flushing Urinals Supporting Statement." Appendix B: References for Calculation Assumptions.
[1600] If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.
[1601] 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
[1602] ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx
[1603] 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.
[1604] 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.[1605]

DEEMED MEASURE COST

The incremental cost for the EV charger is assumed to be $84 for a non-networked charger and $47 for a networked charger.[1606]

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

[1605] Based on Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See 'Lvl2EVChrgrsv2_3.xls'.
[1606] Based on Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See 'Lvl2EVChrgrsv2_3.xls'.

= 278 hours[1607]

Hours_P = Total Annual Hours Plugged In

= 3,511hours[1608]

Hours_PS = Annual Standby Hours Plugged In

= Hours_P - Hours_C

= 3,233 hours

Hours_US = Annual Standby Hours Unplugged

= 8760 - Hours_P

= 5,249 hours

SP_base = Baseline Average Standby Power (W)

= 3.7 for non-networked, 9.9 for networked[1609]

SP_EEp = Efficient Average Standby Power (W) with vehicle plugged in

= 3.5 for non-networked, 3.2 for networked[1610]

SP_EEu = Efficient Average Standby Power (W) in no vehicle mode

= 2.1 for non-networked, 2.5 for networked[1611]

ΔkWh per non-networked charger = (((3,233 + 5,249) * 3.7) - (3,233 * 3.5 + 5,249 * 2.1))/ 1000)

= 9.0 kWh

ΔkWh per networked charger = (((3,233 + 5,249) * 9.9) - (3,233 * 3.2 + 5,249 * 2.5))/ 1000)

= 60.5 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = AveragekW * CF

Where:

AveragekW = Average electric demand during standby.

[1607] Based on Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See ‘Lvl2EVChrgrsv2_3.xls’.

[1608] Based on Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See ‘Lvl2EVChrgrsv2_3.xls’.

[1609] 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).

[1610] 2021 ENERGY STAR QPL of Residential EVSE. Averaged Partial On Mode Input Power (W) and Idle Mode Input Power (W). See Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See ‘Lvl2EVChrgrsv2_3.xls’.

[1611] 2021 ENERGY STAR QPL of Residential EVSE. See Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See ‘Lvl2EVChrgrsv2_3.xls’.

Non-networked = (((3.7-3.5) * 3233/8482) + ((3.7-2.1) * 5249/8482))/1000

= 0.00107 kW

Networked = (((9.9-3.2) * 3233/8482) + ((9.9-2.5) * 5249/8482))/1000

= 0.00713 kW

CF = Summer peak coincidence factor

= 1

FOSSIL FUEL 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-V03-230101

REVIEW DEADLINE: 1/1/2025

5.7.4 Heat Pump Swimming Pool Heater

DESCRIPTION

This measure is applicable to electric heat pump pool heaters in residential applications. Heat pumps capture heat and move it from one place to another. The saving equations presented herein comprise three aspects of pool heating: convective heat loss via pool surface area due to water and air temperature differential, initial heat of full pool volume for seasonal pool use and reheat of pool refill on year round pools, and the heating of added pool water to offset water loss through evaporation.[1612] This measure applies to replacing either a gas-fired pool heater or a an electric resistance pool heater. If baseline equipment is a gas-fired pool heater, electric energy impacts result in additional electrical usage, but lower overall site energy usage.

This measure is only applicable to inground or outdoor single family home pools and is not applicable to spas. This measure is not applicable to community pools in multifamily housing complexes.[1613]

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a heat pump that is more efficient than Illinois energy code. This type of heat pump is designed to heat pool water for residential sized pools. Compliance condition of the equipment is that it is an AHRI-certified heat pump pool heater.

DEFINITION OF BASELINE EQUIPMENT

The baseline reflects the existing pool water heater which could be natural gas, electric resistance or a less electric efficient heat pump water heater. The baseline equipment must be less efficient than that new equipment.

Heating Type	Heat Pump Efficiency
Natural Gas	82% Thermal Efficiency[1614]
Electric Resistance	100%
Heat Pump	3.5 COP

The California Appliance Efficiency Regulations (Title 20) requires a minimum coefficient of performance (COP) of 3.5 for heat pump pool heaters and a minimum thermal efficiency (TE) of 82% for all natural residential pool water heaters.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

15 years.[1615]

[1612] ASHRAE Handbook: HVAC Applications, 2019, pg 51.25. ASHRAE states that except in aboveground pools and rare cases where cold groundwater flows past the pool walls, conductive losses through pool walls are small and can be ignored. ASRHAE additionally indicates that radiation losses that occur due to sky temperature differentials
at night may be offset by solar heat gains of an unshaded pool during the day.

[1613] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-family, and Commercial/Industrial Measures Version 9

[1614] Department of Energy. "10 CFR 430.32 - Energy and water conservation standards and their effective dates." Section (k) (2).

[1615] Database for Energy Efficient Resources (DEER). "2014 DEER Update Study." July 17, 2013.
http://www.deeresources.com/files/home/download/DEER2014UpdatePlan-July2013-v1.pdf

DEEMED MEASURE COST

Estimated gross and incremental installation costs are listed below.[1616] Costs include material cost of heat pump, infrastructure for installation, and labor.

Equipment Type	Gross Cost	Incremental Cost
Gas Heater	$5,158	N/A
Heat Pump Heater	$7,074	$1,916

LOADSHAPE

Loadshape R15 - Residential Pool Pumps

COINCIDENCE FACTOR

The prescribed value for the coincidence factor is 0 for outdoor pools and is 0.8 for indoor pools.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Non fuel switch measures:

Net site energy consumed at the site is calculated below:

$$\Delta kWh = \frac{(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap})}{3{,}412} * \left[\left(\frac{F_{fuel\ baseline}}{E_{t,baseline}}\right) + \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)\right]$$

Fuel switch measures:

Fuel switch measures must produce positive total lifecycle energy savings (i.e., reduction in Btus at the premises) in order to qualify. This is determined as follows:

SiteEnergySavings (MMBTUs) = [FossilHeatReplaced] – [ElectricHeatAdded]

FossilHeatReplaced $= \frac{(BTU_{Surface}+BTU_{Reheat}+BTU_{Evap})}{1{,}000{,}000} * \left[\left(\frac{F_{fuel\ baseline}}{E_{t,baseline}}\right)\right]$

ElectricHeatAdded $= \frac{(BTU_{Surface}+BTU_{Reheat}+BTU_{Evap})}{1{,}000{,}000} * \left[\left(\frac{F_{fuel\ baseline}}{E_{t,baseline}}\right) + \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right)\right]$

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:

[1616] California Technical Reference Manual for Energy Efficiency. Southern California Edison (SCE). 2021. "SWRE005-01 Cost Analysis.xlsm."

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

Where:

$BTU_{Surface}$[1617] = Annual heating energy load contributed by convection/radiation heat losses via pool surface

$= (T_{pool} - T_{amb}) * A_{pool} * U * [hrs - (hrs_{cover} - ESF_{cover,surface})]$

BTU_{Reheat}[1618] = Annual heating energy load contributed by heating the full volume of pool water

$= V_{pool} * 8.33 * (T_{pool} - T_{main}) * F_{Reheat}$

BTU_{Evap}[1619] = Annual heating energy load contributed by evaporation

$= 0.1 * AF * A_{pool} * (P_{\omega} - P_{dp}) * (T_{pool} - T_{main}) * [hrs - (hrs_{cover} * ESF_{cover,evap})]$

$F_{elec,baseline}$ = Baseline electric pool heater factor; used to account for the presence or absence of an electric pool heater.

= 1.0 if baseline system is electric resistance pool heater

= 0 if baseline system is not an electric resistance pool heater

$F_{fuel,baseline}$ = Baseline fossil fuel pool heater factor; used to account for the presence or absence of a fossil fuel-fired pool heater.

= 1.0 if baseline system is fossil fuel-fired pool heater

= 0 if baseline system is not a fossil fuel-fired pool heater

$COP_{baseline}$ = Coefficient of performance, ratio of output energy/input energy of baseline electric resistance pool heater, if present.

= 1.0 if heater is electric resistance; 3.5 if heater is heat pump

COP_{ee} = Coefficient of performance, ratio of output energy/input energy of heat pump pool heater.

= Actual

$E_{t,baseline}$ = Thermal efficiency of baseline fossil fuel-fired pool heater, if present.

= 0.82 if unknown

T_{pool} = Pool temperature set point, (°F).

1617 ASHRAE Handbook: HVAC Applications, 2019, Ch 51 Service Water Heating, Swimming Pools/Health Clubs.
1618 Ibid, eqn. 14
1619 ASHRAE Handbook: HVAC Applications, 2019, Ch 6 Indoor Swimming Pools, eqn. 3, multiplied by required heating temperature difference

= Actual

T_{amb} = Average temperature of surrounding ambient air, (°F). If pool is indoors, this is the indoor temperature of room with pool from application. For outdoor pools, see "Ambient Air Temperature and Pressure (T_{amb} and P_{dp})" table below.

T_{main} = Supply water temperature in water main, (°F). See "Cold Water Inlet Temperature (T_{main})" table below.

A_{pool} = Surface area of pool, (ft^2). From application. Assistance in determining the area of common pool shapes as follows:[1620]

Elliptical: 3.14 x short radius x long radius

Kidney Shaped: 0.45 x length x (width at one end x width at other end)

Oval: 3.14 x radius^2 + (length of straight sides x width)

Rectangular: length x width

V_{pool} = Volume of pool water, (gallons)

= ActualFrom application.

F_{Reheat} = Factor capturing annual number of times full pool volume is heated to the desired temperature, whether as the result of refill or heating of pool water from ground water temperature at start of season. From application.

= 0 if pool is filled by delivery service providing preheated water

= 1 if otherwise[1621]

U = Surface heat loss coefficient, (BTU/hr ft^2 °F)[1622]

= 3.9 for indoor pool

= 5.3 for outdoor pool, sheltered

= 6.6 for outdoor pool, unsheltered

AF = Activity Factor, consideration of activity within pool, allowing for splashing and a limited area of wetted deck.[1623]

= 0.5

P_{ω} = Saturation vapor pressure taken at surface water temperature, (in. Hg). See "Saturation Vapor Pressure (P_{ω})" table below based on pool water temperature.

P_{dp} = Saturation pressure at dew point, (in. Hg). See "Ambient Air Temperature and Pressure (T_{amb} and P_{dp})" table below.

[1620] Guidance for determining surface area of common pool shapes can be found at ASHRAE Handbook: HVAC Applications, 2019.

[1621] The water temperature of an undrained pool between swim seasons is assumed to have reached the water main temperature by the beginning of the next swim season. If the pool remains open throughout the year, it is assumed the pool undergoes one effective full pool volume reheat from water main temperature for cleaning and other maintenance (CDC, Healthy Swimming, Operating Public Swimming Pools).

[1622] ASHRAE Handbook: HVAC Applications, 2019, Ch 51, eqn. 15. Surface heat loss coefficient adjusted from ASHRAE Handbook rolled up surface heat transfer conservations by discounting contribution of evaporation (50-60%) and applying the following assumption for wind velocity: Indoor pools experience average wind speeds less than 3.5 mph (10.5x0.5x0.75), outdoor sheltered pools experience wind speeds between 3.5 and 5 mph (10.5x0.5), and outdoor unsheltered pools experience wind speeds above 5 mph (10.5x0.5x1.25).

[1623] ASHRAE Handbook, Applications, 2019, Ch 6, Table 1 hrs = Total annual swimming season hours. From application. Hours shall reflect the total annual hours through the swimming season (number of days between season opening and season closing x 24).

hrs_{cover} = Total annual hours pool covered during the swimming season. From application. Hours shall reflect the total hours pool covered during the swimming season. Set equal to 0 if pool is left uncovered throughout swimming season.

$ESF_{cover,surface}$ = Energy Savings Factor of pool cover to insulate from convective and radiation heat losses

= 0.80[1624]

$ESF_{cover,evap}$ = Energy Savings Factor of pool cover to insulate from evaporative heat loss

= 0.95[1625]

0.1 = Simplified empirically derived evaporation factor considering latent heat and air flow.[1626] Assumes 1,000 BTU/lb of latent heat required to change water to vapor at surface water temperature and air velocity over water surface ranging from 10 to 30 fpm, (lb/hr ft^2 in. hg)

8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit

3,412 = Conversion factor, one kWh equals 3,412 BTU

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[1627] Supply main temperatures based on the annual outdoor temperature are shown below.

Climate Zone	Annual Average Outdoor Temperature (°F)[1628]	T_{main} (°F)
1 (Rockford)	49.2	55.2
2 (Chicago)	51.4	57.4
3 (Springfield)	53.0	59.0
4 (Belleville)	57.3	63.3
5 (Marion)	56.5	62.5

Saturation Vapor Pressure (P_{ω})

Lookup saturation vapor pressure taken at surface water temperature for indoor and outdoor pools from the table below, based on pool temperature.[1629]

1624 U.S. D.O.E., Swimming Pool Covers.

1625 National Plasterers Council, Effectiveness of Pool Covers to Reduce Evaporation from Swimming Pools, prepared by California Polytechnic State University, January 2016.

1626 Simplified constant presented in ASHRAE Handbook: HVAC Application 2019 Ch 6 based on empirically derived eqn (2) constants and ASHRAE's variable assumptions

1627 Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.

1628 Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals. https://www.ncdc.noaa.gov/cdo-web/datatools/normals

1629 ASHRAE Handbook: Fundamentals 2017, Ch 1 Psychrometrics, Table 3 Thermodynamic Properties of Water at Saturation

Pool Temperature, T_{pool} (°F)	P_{ω} (in. Hg)
72	0.79
74	0.85
76	0.91
78	0.97
80	1.03
82	1.10
84	1.18

Ambient Air Temperature and Pressure (T_{amb} and P_{dp})

Indoor pools shall apply ambient air temperature from application based on facility set point temperature. Lookup saturation vapor pressure based on facility set point temperature and relative humidity (RH) from the table below, based on psychrometric analysis. Interpolation may be performed for indoor pool ambient temperatures not listed.

Indoor Pool Temperature, T_{amb} (°F)	Indoor Pool, P_{dp} (in. Hg)		
	RH 50%	RH 55%	RH 60%
72	0.40	0.44	0.47
74	0.42	0.47	0.51
76	0.45	0.50	0.54
78	0.48	0.53	0.58
80	0.52	0.56	0.62
82	0.55	0.61	0.66
84	0.59	0.65	0.71
86	0.63	0.69	0.75

For outdoor pools, lookup T_{amb} and P_{dp} from the table below based on location. Ambient temperature averages for outdoor pools apply a 4-month swimming season.

Climate Zone	Outdoor Pool Temperature T_{amb} (°F)[1630]	Outdoor Pool P_{dp} (in. Hg)[1631]
1 (Rockford)	69.6	0.52
2 (Chicago)	73.4	0.53
3 (Springfield)	72.9	0.58
4 (Belleville)	73.9	0.60
5 (Marion)	74.8	0.62

Fuel Switch Example

A gas pool heater is replaced with a heat pump pool heater at a single family home located near Chicago. The swimming season spans 4 months (2,904 hours) per year and the pool is left uncovered at night. The pool is 15 ft by 30 ft and has a volume of 17,600 gallons, and is sheltered from winds by the house and backyard trees. The pool temperature is maintained at 80°F. The replaced gas pool heater has an efficiency of 82% and the heat pump pool heater has an efficiency of 5.0 COP. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings

[1630] DOE Weather Data, TMY3 (Typical Meteorological Year), developed by NREL. Adjusted to apply to outside air temperature from June 1 to September 30 in each climate zone.

[1631] DOE Weather Data, TMY3 (Typical Meteorological Year), developed by NREL. Saturation pressure at dew point calculated as a function of dew point and atmospheric pressure. Values averaged from June 1 to September 30 in each climate zone.

and Annual Fossil Fuel Energy Savings are calculated as below.

$\Delta kWh = (BTUSurface + BTUReheat + BTUEvap)/3{,}412 \times (Felec{,}baseline/COPbaseline - 1/COPee)$

$\Delta kW = \Delta kWh/hrs \times CF$

$\Delta MMBtu = (BTUSurface + BTUReheat + BTUEvap)/1{,}000{,}000 \times Ffuel{,}baseline/Et{,}baseline$

where:

$BTUSurface = (Tpool - Tamb) \times Apool \times U \times [hrs - (hrscover \times ESFcover{,}surface)]$

$BTUReheat = Vpool \times 8.33 \times (Tpool - Tmain) \times FReheat$

$BTUEvap = 0.1 \times AF \times Apool \times (P\omega - Pdp) \times (Tpool - Tmain) \times [hrs - (hrscover \times ESFcover{,}evap)]$

Tpool = 80, from application

Tamb = 73.4, from Ambient Air Temperature and Pressure section based on location from application

Apool = width x length = 15’ x 30’ = 450 square feet

Width and length from application

U = 5.3, from Summary of Variables and Data Sources table based on conditions from application

hrs = 2,904, from 121 day season or application

hrscover = 0, from application

ESFcover,surface = 0.8, from Summary of Variables and Data Sources table

Vpool = 17,600, from application

Tmain = 57.4, from Cold Water Inlet Temperature table based on location from application

FReheat = 1, from Summary of Variables and Data Sources table

AF = 0.5, from Summary of Variables and Data Sources table

Pω = 1.03, from Saturation Vapor Pressure section based on pool temperature from application

Pdp = 0.53, from Ambient Air Temperature and Pressure section based on location from application

ESFcover,evap = 0.95, from Summary of Variables and Data Sources table

Felec,baseline = 0, from Summary of Variables and Data Sources table based on application

COPee = 5.0, from application

CF = 0, from Summary of Variables and Data Sources table based on application

Ffuel,baseline = 1, from Summary of Variables and Data Sources table based on application

Et,baseline = 0.82, from application

$BTUSurface = (80 - 73.4) \times 450 \times 5.3 \times [2{,}904 - (0)] = 45{,}711{,}864\ Btu$

$BTUReheat = 17{,}600 \times 8.33 \times (80 - 57.4) \times 1 = 3{,}313{,}341\ Btu$

$BTUEvap = 0.1 \times 0.5 \times 450 \times (1.03 - 0.53) \times (80 - 57.4) \times [2{,}904 - (0)] = 738{,}342\ Btu$

$\Delta kWh = (45{,}711{,}864 + 3{,}313{,}341 + 738{,}342)/3{,}412 \times (0 - 1/5) = -2{,}917\ kWh$

= -10.0 $\Delta MMBtu$ of Electric Site Energy

$\Delta kW = -2{,}917 \times 0 = 0\ kW$

$\Delta MMBtu$=(45,711,864+3,313,341+738,342)/1,000,000×1/0.82=60.7 $\Delta MMBtu$ of Natural Gas Site Energy

Converted to Therms this is 607

$\Delta MMBtu$ Site Energy Savings is = 60.7 $MMBtu$ – 10.0 $MMBtu$ = 50.7 $MMBtu$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{(BTU_{Surface} + BTU_{Reheat} + BTU_{Evap})}{3{,}412} * \left(\frac{F_{elec,baseline}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right) * \frac{CF}{hrs}$$

Where CF value depends on location of pool

CF = 0 for outdoor pools

CF = 0.8 for indoor pools

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-MSC-HPPH-V01-230101

REVIEW DEADLINE: 1/1/2026

5.7.5 Tree Planting

DESCRIPTION

This measure describes savings from a program where utility sponsored staff work with homeowners or building operators to determine the appropriate location and ultimately plant trees to maximize HVAC savings.

How measure saves energy:

1. Trees when in full foliage block direct sunlight onto exterior surfaces of residences, and in the cooling season reduce energy use. Primary effects are reduced insulation into residences through windows. Secondary effects are reduced wall and roof temperatures which reduce conduction through walls and roofs into residences.
2. Trees when in full foliage block winds and associated infiltration into residences. This saves both heating and cooling energy since outdoor air is generally either hotter or colder than the desired indoor temperature.
3. Because trees have differential winter impacts, based on whether they are leaf-retaining (Coniferous) or leaf-shedding (Deciduous), there are significantly differential effects of tree types for each facing wall of a residence. Therefore, eligibility requirements for types of trees planted on specific residence wall faces have been set to maximize savings and minimize losses due to trees.
4. Trees must provide shading to at least the 3rd story of a home in the cooling season and eligibility therefore requires trees to be a minimum of 30 feet tall when fully mature.

Markets measure serves:

This measure provides benefits to single-family residences as well as multi-family residences. It provides benefits for all types of homes, from 1 story to 3 story residences. Trees must be planted within 15 feet of the walls of homes so that they provide shading during summer days when the sun is at a high angle.

Limitations to measure applicability:

This measure is inapplicable to residences that currently have trees shading the face where the trees are proposed to be added (that is, the face of the existing residence where the tree is proposed must currently be unshaded). Coniferous trees are ineligible on the East and South faces of residences because these trees block beneficial sunlight in the heating season, which reduces annual savings severely. Similarly, Deciduous trees are ineligible on North faces of residences because they lose their leaves in winter and therefore have a minimal wind-blocking effect on infiltration during prevailing NW and W winter winds; in addition, because they are on the North face, they provide attenuated benefits for summer cooling energy use.

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

Trees must be horticulturally defined as either leaf-retaining (e.g., Coniferous) or leaf-shedding (e.g., Deciduous). The eligibility of tree types are dependent on the orientation of the wall of the residence being shaded as follows:

1. On North-facing walls, only Coniferous trees (i.e., trees that retain leaves all year) are eligible.
2. On East- and South-facing walls, only Deciduous trees (i.e., trees that lose all leaves in Fall) are eligible.
3. On West-facing walls, both deciduous and coniferous trees are eligible.
4. Trees must be minimum 30 ft tall when fully mature and have a lifetime of at least 20 years in Midwest climate.
5. Trees must be planted within 15 feet of the wall that they are shading and no closer than 20 feet apart.

DEFINITION OF BASELINE EQUIPMENT

Residence wall where trees are proposed to be planted currently must be fully or partially unshaded OR currently be planted with “ineligible” trees that will be removed and replaced with “eligible” trees. If the residence wall currently is partially shaded, the proposed tree must be planted in front of the currently unshaded portion of the wall.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Savings from tree planting take a number of years to be realized as significant growth is required before the shading makes a significant impact. The length of time before savings are fully achieved will be dependent on a number of factors including size of tree when planted, proximity to building and the speed of growth. This measure has been designed based on the assumption that savings would not be achieved for the first five years and would then be realized from year 6 and for a further 20 years.

However, in order to simplify the implementation of this measure, a reduced savings is claimed from year 1 and for an assumed measure life of 25 years, which results in an equivalent present value of lifetime savings. This results in a 79% multiplier[1632] applied to the calculated annual savings for the measure.

If there is reason to believe that the length of time before savings are achieved is significantly different to the 5 years assumed, an alternative multiplier can be applied.

DEEMED MEASURE COST

Use actual installed cost per tree planted.

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%[1633]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%[1634]

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

= 46.6%[1635]

1632 Assuming Real Discount Rate of 0.46%.

1633 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1634 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)’.

1635 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 ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\text{Total } \Delta kWh = (\Delta kWh_{HeatingDirectSolar} + \Delta kWh_{CoolingDirectSolar} + \Delta kWh_{HeatingInfiltration} + \Delta kWh_{CoolingInfiltration}) * (1 - LMR) * NPVDiscount$$

Where:

$\Delta kWh_{HeatingDirectSolar}$ = Annual heating savings due to reduction in Direct Solar Gain

= #Trees * ThermsHeatingIncrease/Tree * 100,000 / 3,412 / ηHeat * %ElectricHeat

#_Trees = total number of eligible trees planted
= actual number of eligible trees planted on any face of the residence

ThermsHeatingIncrease/Tree = net annual therms of heating increase per tree due to shading, based on the average annual savings of eligible trees planted on all faces of the residence

= - 3.2 Therms/tree [1636]

100,000 = conversion of Therms to BTUs

3,412 = conversion BTUs to kWh

ηHeat = Efficiency of heating system

= In order to account for the long-term aspect of this measure and the the likely replacement of existing heating and cooling equipment during the lifetime of this measure, the following system efficiency assumptions should be used:

Efficiency Assumption	System Type	New Baseline Efficiency
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

[1636] Savings are based upon a modeling spreadsheet provided by Leidos – see 'Shade Tree Energy Savings – REVISED.xlsx'. This analysis includes a large number of assumptions and therefore resultant savings were trued up against TRM assumptions of full cooling energy consumption to result in a percentage savings that was consistent with a number of reviewed studies (namely: Home Energy Magazine: "Shade Trees as a Demand-Side Resource", Energy and Buildings: "Peak power and cooling energy savings of shade trees", and Ecological Economics: "Energy Savings from tree shade". These references can be found in the reference folder.)

%ElectricHeat = Percent of homes that have electric space heating

= 100 % for Electric Resistance or Heat Pump

= 0 % for Natural Gas

= If unknown[1637], 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%**

$\Delta kWh_{CoolingDirectSolar}$ = Annual cooling savings due to reduction in Direct Solar Gain

= #Trees * Ton-hrCoolingSaved/Tree * 12,000 / (1,000 * ηCool) * %Cool

Ton-hrCoolingSaved/Tree = Net annual Ton-hours of cooling saved per tree due to shading, based on the average annual savings of eligible trees planted on all faces of the residence

= 137.3 ton-hrs/year/tree[1638]

12,000 = conversion of ton-hours to BTUs

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

= In order to account for the long-term aspect of this measure and the the likely replacement of existing heating and cooling equipment during the lifetime of this measure, the following system efficiency assumptions should be used:

Efficiency Assumption	System Type	New Baseline Efficiency
ηCool	Central AC	13 SEER
	Heat Pump	14 SEER

%Cool = Percent of homes that have cooling

[1637] 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.

[1638] Savings are based upon a modeling spreadsheet provided by Leidos – see 'Shade Tree Energy Savings – REVISED.xlsx'. This analysis includes a large number of assumptions and therefore resultant savings were trued up against TRM assumptions of full cooling energy consumption to result in a percentage savings that was consistent with a number of reviewed studies (namely: Home Energy Magazine: "Shade Trees as a Demand-Side Resource", Energy and Buildings: "Peak power and cooling energy savings of shade trees", and Ecological Economics: "Energy Savings from tree shade". These references can be found in the reference folder.)

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown (for use in program evaluation only)[1639]	66%

$\Delta kWh_{HeatingInfiltration}$ = Annual heating savings due to reduction in infiltration

= #Trees * CFM50/sqft * Area/ N_Heat * %Reduction_HeatingInfiltration/Tree * 60 * 24 * HDD60 * 0.018 / (COPHeating * 3,412) * %ElectricHeat

CFM50/sqft = Average CFM of infiltration per square foot of residence floor area based on 50 pascal pressure differential (This is a Customer Input of degree of leakage rate of house; Assumes the CFM50 leakage rates in the following table; assumes CFM50 leakage rates were based on a typical 2,250 sq. ft. residence.)

Shade Tree ECM Constants	CFM50/sqft	CFM50	Source
Leaky/Low Insulation	2.22	5,000 CFM at 50 pascal	Estimate for Leaky 2,250 sqft dwelling
Average/Average Insulation Or if Unknown	1.51	3,400 CFM at 50 pascal	Estimate for Average 2,250 sqft dwelling
Tight/High Insulation	1.00	2,250 CFM at 50 pascal	Estimate for Tight 2,250 sqft dwelling

Area = floor area of residence

= actual

%Reduction_HeatingInfiltration/Tree = Average infiltration reduction per tree during heating season due to tree blocking wind, based on average annual savings of eligible trees planted on all faces of the residence.

= 0.47% infiltration reduction per tree [1640]

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone, building height and exposure level:[1641]

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

[1639] 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

[1640] Savings are based upon a modeling spreadsheet provided by Leidos – see 'Shade Tree Energy Savings – REVISED.xlsx'. This analysis includes a large number of assumptions and therefore resultant savings were trued up against TRM assumptions of full cooling energy consumption to result in a percentage savings that was consistent with a number of reviewed studies (namely: Home Energy Magazine: "Shade Trees as a Demand-Side Resource", Energy and Buildings: "Peak power and cooling energy savings of shade trees", and Ecological Economics: "Energy Savings from tree shade". These references can be found in the reference folder.)

[1641] 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_heat (by # of stories)			
	1	1.5	2	3
4 (St Louis, MO)	25.4	22.5	20.7	18.3
5 (Paducah, KY)	27.8	24.6	22.6	20.0

60 = conversion of ton-hours cooling to BTUs

24 = conversion of Watts to kWh

HDD = Heating Degree Days

= Dependent on location:[1642]

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

0.018 = Specific Heat capacity of Air (BTU/Cu.Ft./F)

$\Delta kWh_{CoolingInfiltration}$ = Annual cooling savings due to reduction in infiltration

= #Trees * CFM50/sqft * Area / N_Cool * %_ ReductionCoolingInfiltration/Tree * 60 * 24 * CDD65 * LM * 0.018 / (ηCool * 1000) * %Cool

N_cool = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

=Dependent on location and number of stories:[1643]

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

%Reduction_CoolingInfiltration/Tree = Average infiltration reduction per tree during cooling season due to tree blocking wind, based on average annual savings of eligible trees planted on all faces of the residence.

[1642] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.

[1643] 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".

= 2.26% infiltration reduction per tree [1644]

CDD = Cooling Degree Days

= Dependent on location:[1645]

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

LM = Latent Multiplier

= Multiplies the CDD dry bulb temperature difference by a factor that accounts for the additional energy needed to dehumidify air when in cooling mode

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

LMR = Lifetime Mortality Rate – i.e. assumed percentage of trees that do not go on to provide the savings characterized in this measure.

= 18% for single family and 39% for multi family[1646]

NPVDiscount = Multiplier to reduce annual savings claimed from year 1 to account for assumed length of time before savings are realized.

= 79%[1647]

[1644] Savings are based upon a modeling spreadsheet provided by Leidos – see 'Shade Tree Energy Savings – REVISED.xlsx'. This analysis includes a large number of assumptions and therefore resultant savings were trued up against TRM assumptions of full cooling energy consumption to result in a percentage savings that was consistent with a number of reviewed studies (namely: Home Energy Magazine: "Shade Trees as a Demand-Side Resource", Energy and Buildings: "Peak power and cooling energy savings of shade trees", and Ecological Economics: "Energy Savings from tree shade". These references can be found in the reference folder.)

[1645] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

[1646] Assumption based on McPherson, "Energy-Saving Potential of Trees in Chicago", page 24.

[1647] Based on assumption that savings would not be realized for first 5 years and then continue for 20 years. Applying this multiplier and claiming savings from year one and for a measure life of 25 years results in equivalent NPV of lifetime savings, applying a Real Discount Rate of 0.46%. If reason to believe savings will be realized after a significantly different length of time, and alternative multiplier can be calculated.

For example: Assuming 5 eligible trees are planted around home with average leakage and Insulation Levels; 2,500 Sq. Ft. floor area in a 2 story Single Family Residence in Springfield with an Air Source Heat Pump with unknown efficiency.

$\Delta kWh = (\Delta kWh_{HeatingDirectSolar} + \Delta kWh_{CoolingDirectSolar} + \Delta kWh_{HeatingInfiltration} + \Delta kWh_{CoolingInfiltration}) * (1 - LMR) * NPVDiscount$

$\Delta kWh_{HeatingDirectSolar}$ = #Trees * ThermsHeatingIncreased/Tree * 100,000 / 3,412 / ηHeat * %ElectricHeat

= 5 * -3.2 * 100,000 / 3,412 / 2.04 * 100%

= -230 kWh

$\Delta kWh_{CoolingDirectSolar}$ = #Trees * Ton-hrCoolingSaved/Tree * 12,000 / (1,000 * ηCool) * %Cool

= 5 * 137.3 * 12,000 / (1,000 * 14) * 100%

= 588 kWh

$\Delta kWh_{HeatingInfiltration}$ = #Trees * CFM50/sqft * Area/ N_Heat * %Reduction_HeatingInfiltration/Tree * 60 * 24 * HDD60 * 0.018 / (COPHeating * 3,412) * %ElectricHeat

= 5 * 1.51 * 2,500/19.7 * 0.47% * 60 * 24 * 4,379 * 0.018 / (2.04 * 3,412) * 100%

= 73 kWh

$\Delta kWh_{CoolingInfiltration}$ = #Trees * CFM50/sqft * Area / N_Cool * %_ ReductionCoolingInfiltration/Tree * 60 * 24 * CDD65 * LM * 0.018 / (ηCool * 1000) * %Cool

= 5 * 1.51 * 2,500/33.4 * 2.26% * 60 * 24 * 1,108 * 3.7 0.018 / (14 * 1,000) * 100%

= 97 kWh

ΔkWh = (-230 + 588 + 73 + 97) * (1 – 0.18) * 0.79

= 342 kWh (68.4 kWh per tree)

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = kWh_{Cool} / FLH\_Cooling * CF * (1-LMR) * NPVDiscount$

Where:

kWh_{Cool} = Total cooling kWh savings from measure

= $\Delta kWh_{CoolingDirectSolar} + \Delta kWh_{CoolingInfiltration}$

FLH_cooling = Full load hours of air conditioning

= Dependent on location:[1648]

[1648] 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.

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%[1649]

CF_{SSP} = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72% [1650]

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

= 46.6% [1651]

For Example, using example from above and CF_{SSP} for heat pumps:

ΔkW = kWh_{Cool} / FLH_Cooling * CF * (1 – LMR) * NPVDiscount

kWh_{Cool} = 588 + 97

= 685

ΔkW = 685 / 760 * 0.72 * (1-0.18) * 0.79

= 0.420

FOSSIL FUEL SAVINGS

$$\Delta Therms = (\Delta Therms_{HeatingDirectSolar} + \Delta Therms_{HeatingInfiltration}) * (1- LMR) * NPVDiscount$$

Where:

$\Delta Therms_{HeatingDirectSolar}$ = Annual therm savings due to reduction in direct solar gain

= #_Trees * ThermsHeatingIncreased/Tree / ηHeat * %FossilHeat

ThermsHeatingIncreased/Tree = Net annual therms of heating saved per tree due to shading and infiltration effects, based on the average annual savings of eligible trees planted on all faces of the residence.

[1649] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1650] 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)'.

[1651] 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.

= -3.2 Therms/Tree

ηHeat = as defined above

%FossilHeat = Percent of homes that have fossil fuel space heating

= 100 % for Fossil fuel

= 0 % for Electric Resistance or Heat Pump

= If unknown[1652], 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%**

Note: If a measure is supported by a gas and electric utility, utilize the assumptions above for the gas utility

$\Delta Therms_{HeatingInfiltration}$ = Annual therm savings due to reduction in infiltration

= #Trees * CFM50/SqFt * Area/ N_Heat * %_ ReductionHeatingInfiltration/Tree * 60 * 24 * HDD60 * 0.018 / (ηHeat * 100,000)

[1652] 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: Assuming 5 eligible trees are planted around home with average leakage and Insulation Levels; 2,500 Sq. Ft. floor area in a 2 story Single Family Residence in Springfield with furnace with system efficiency of 68%.

$$\Delta Therms = (\Delta Therms_{HeatingDirectSolar} + \Delta Therms_{HeatingInfiltration}) * (1 – LMR) * NPVDiscount$$

$\Delta Therms_{HeatingDirectSolar}$ = #Trees * ThermsHeatingIncreased/Tree / ηHeat * %FossilHeat

= 5 * -3.2/0.68 * 100%

= -23.5 Therms

$\Delta Therms_{HeatingInfiltration}$ = #Trees * CFM50/SqFt * Area/ N_Heat * %_ ReductionHeatingInfiltration/Tree * 60 * 24 * HDD60 * 0.018 / (ηHeat * 100,000)

= 5 * 1.51 * 2,500/19.7 * 0.47% * 60 * 24 * 4,379 * 0.018 / (0.68 * 100,000) * 100%

= 7.5 Therms

ΔTherms = (-23.5 + 7.5) * (1 – 0.18) * 0.79

= - 10.4 Therms

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

n/a

DEEMED O&M COST ADJUSTMENT CALCULATION

n/a

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REVIEW DEADLINE: 1/1/2025