Volume 3: Residential Measures

Ameren Missouri TRM – Volume 3: Residential Measures Revision Log

Revision	Date	Description
1.0	05/30/2018	Initial version filed for Commission approval.
2.0	12/21/2018	Updated "Deemed Tables" with PY2017 Evaluation results per Stipulation and Agreement (File No. EO-2018-0211). Added Demand Response language per Stipulation and Agreement.
3.0	1/01/2020	Updated "Deemed Tables" with PY2018 Evaluation results. Also includes revisions to HVAC measures and multifamily measures, based on feedback from evaluation contractor. This includes updates to Volume 3 of the TRM.
4.0	10/15/2020	Updated "Deemed Tables" with PY2019 Evaluation results and other revisions to improve consistency with Deemed tables.
5.0	09/15/21	Updated "Deemed Tables" with PY2020 Evaluation results and other revisions to improve consistency with Deemed tables.
6.0	09/26/2022	Updated "Deemed Tables" with PY2021 Evaluation results and other revisions to improve consistency with Deemed Tables. Other revisions include updates to incremental costs for low flow showerheads, in-service rates for low flow showerheads and faucet aerators based on PY2021 evaluation, incorporation of SEER to SEER2 and HSPF to HSPF2 conversion factors due to upcoming Code of Federal Regulation testing procedures, and updates to PTHP and PTAC baseline code efficiencies.
7.0	10/05/2023	Addition of Pay As You Save (PAYS®) ISR's. Added language to clarify that ccASHP's must meet the majority of a home's heating needs. Updated HVAC baselines for heat pumps to CFR standards, with a TRM effective date of 1/1/2024 to allow for sell-through; Updates to lighting measures to address EISA updates to general service lamps (GSL), effective 8/1/2023. Updated deemed costs of light bulbs to reflect first year cost per bulb.
8.0	12/1/2024	Removed several measures currently not active in the programs and added cool roof measures. Updated incremental cost for some measures, including Heating and Cooling CAC/ASHP. Reviewed and updated all measures including source documentation.

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Volume 3: Residential Measures

3.1 Appliances

3.1.1 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 that does not meet ENERGY STAR Efficiency Requirements.[3]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The measure life is assumed to be 9 years.[4]

DEEMED MEASURE COST
The incremental cost for this measure is dependent on the Air Purifier size in CADR of Smoke.[5]

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[1] Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf; 'Air-Cleaner-Performance-FAQs.pdf'.
[2] ENERGY STAR® Product Specification for Room Air Cleaners - Eligibility Criteria Version 2.0, effective October 17, 2020 . https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%202.0%20Room%20Air%20Cleaners%20Specification%20%28Rev.%20May%202022%29.pdf; 'ENERGY STAR Version 2.0 Room Air Cleaners Specification (Rev. May 2022).pdf'.
[3] ENERGY STAR® Product Specification for Room Air Cleaners - Eligibility Criteria Version 2.0, https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%202.0%20Room%20Air%20Cleaners%20Specification%20%28Rev.%20May%202022%29.pdf; 'ENERGY STAR Version 2.0 Room Air Cleaners Specification (Rev. May 2022).pdf'.
[4] ENERGY STAR Qualified Room Air Cleaner Calculator citing Appliance Magazine, Portrait of the U.S. Appliance Industry 1998, 'ENERGY STAR Appliance Calculator.xlsx'.
[5] 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 ENERGY STAR Purchase Cost ($)	Average Incremental Cost ($)	
			Non-IQ	IQ[6]
30 ≤ Smoke CADR < 100	1.9	$82.49	$8.44	$20.78
100 ≤ Smoke CADR < 150	2.4	$140.43	$22.33	$42.01
150 ≤ Smoke CADR < 200	2.9	$349.00	$92.34	$135.12
200 ≤ Smoke CADR	2.9	$264.49	$44.50	$81.17

LOADSHAPE

HVAC RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = (kWh_base – kWh_eff) * ISR

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

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

IQAdj = Baseline consumption adjustment for IQ program participants to account for a portion of participants who would have utilized the secondary market.[8]

= 1.25 if IQ, 1.0 if non-IQ

SmokeCADR_eff = Smoke CADR for efficient unit

[6] IQ Incremental costs factor in the assumption that a secondhand unit costs on average 50% of a new baseline unit, and that 1/3 of IQ participants would have purchased a unit on the secondhand market. See 'IQ Appliance Calculations.xlsx' for information.

[7] Consistent with ENERGY STAR v.2.0 Room Air Cleaners Data Package and analysis. See file: 'ICF_EPA_AirPurifier_Summary Savings Calculations_043021.xlsx'.

[8] It is assumed that a second-hand unit is on average 1/3 of a measure's EUL years old (6 years). The baseline consumption from the TRM in 2018 was increased by an estimate of 0.4% * 6 years (based on review of the refrigerator/freezer regression algorithm used in the 5.1.8 Refrigerator and Freezer Recycling measure) to account for degradation of performance over time. This second hand consumption was then weighted 1/3: 2/3 current new baseline to estimate a multiplier for IQ participants. See 'IQ Appliance Calculations.xlsx' for information.

	= 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)
	= Actual, if unknown use values provided in table below
ISR	= In-service rate. Actual, or if unknown, 98%[9]

Parameter assumptions for units by CADR Range:[10]

CADR Range	Smoke CADR	Smoke CADR per Watt	Partial On Mode Power (watts)
	Baseline Units		
30 ≤ Smoke CADR < 100	83.3	1.64	2
100 ≤ Smoke CADR < 150	127.6	1.83	2
150 ≤ Smoke CADR < 200	175.2	1.94	2
200 ≤ Smoke CADR	292.9	1.89	2
	Efficient Units		
30 ≤ Smoke CADR < 100	83.3	2.9	0.478
100 ≤ Smoke CADR < 150	127.6	4.08	0.325
150 ≤ Smoke CADR < 200	175.2	4.47	0.562
200 ≤ Smoke CADR	292.9	5.05	0.638

Summer Coincident Peak Demand Savings

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh	= Electric energy savings, as calculated above.
CF	= Summer peak coincidence demand (kW) to annual energy (kWh) factor
	= 0.0004660805

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

[9] Ameren Missouri PY2018 Efficient Products Evaluation Report, https://www.efis.psc.mo.gov/Document/Display/15869, page I-7.

[10] 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_043021.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 & Efficient 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', IL TRM v12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 8.

DEEMED O&M COST ADJUSTMENT CALCULATION

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

MEASURE CODE:

[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.

3.1.2 Clothes Dryer

DESCRIPTION

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR® criteria. ENERGY STAR® qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers.[12] ENERGY STAR® provides criteria for both gas and electric clothes dryers.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

DEEMED MEASURE COST

Dryer Size	Incremental Cost[14]
Standard	$75
Compact	$105

LOADSHAPE

Miscellaneous RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (Load/(CEFbase) - (Load)/CEFeff) * Ncycles * \%Electric$$

Where:

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

Dryer Size	Load (lbs)[15]
Standard	8.45
Compact	3

[12] ENERGY STAR® Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf; 'ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf'.

[13] Based on an average estimated range of 12-16 years. ENERGY STAR® Market & Industry Scoping Report. Residential Clothes Dryers. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf Based on DOE Rulemaking Technical Support Document, LCC Chapter, 2011, as recommended in Navigant ComEd Effective Useful Life Research Report, 'ComEd Effective Useful Life Research Report.pdf', May 2018.

[14] Cost based on ENERGY STAR® Savings Calculator for ENERGY STAR® Qualified Appliances. https://dnr.mo.gov/sites/dnr/files/media/file/2021/01/energy-star-appliance-calculator.xlsx; 'energy-star-appliance-calculator.xlsx'.

[15] Based on ENERGY STAR® test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR® analysis.[16] If product class unknown, assume electric, standard.

Product Class	CEFbase
Vented Electric, Standard (≥ 4.4 ft^3)	3.11
Vented Electric, Compact (120V) (< 4.4	3.01
Vented Electric, Compact (240V) (<4.4	2.73
Ventless Electric, Compact (240V) (<4.4	2.13
Vented Gas	2.84[17]
Electric Heat Pump, Standard (≥ 4.4 ft^3)	3.11
Electric Heat Pump, Compact (120V) (<	3.01

CEFeff = CEF (lbs/kWh) of the ENERGY STAR® unit based on ENERGY STAR® or ENERGY STAR® Most Efficient requirements requirements.[18] 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	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[19]	3.8

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year.[20]

%Electric = The percent of overall savings coming from electricity
= 100% for electric dryers, 5% for gas dryers[21]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001148238

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[16] ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis, https://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Draft%202%20Version%201.0%20Clothes%20Dryers%20Data%20and%20Analysis.xlsx; 'ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.xlsx'.

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

[18] ENERGY STAR® Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

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

[20] Appendix D to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Dryers, https://ecfr.io/Title-10/Part-430/Appendix-D; 'Title 10 Part 430 Appendix D.pdf'.

[21] One hundred percent for electric dryer accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc.). Five percent for gas dryers 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. Value reported in 2015 EPA ENERGY STAR® appliance calculator, https://dnr.mo.gov/sites/dnr/files/media/file/2021/01/energy-star-appliance-calculator.xlsx; 'energy-star-appliance-calculator.xlsx'.

NATURAL GAS ENERGY SAVINGS

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

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

Where:

Therm_convert = Conversion factor from kWh to therm
= 0.03413

%Gas = Percent of overall savings coming from gas
= 0% for electric units and 84% for gas units[22]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[22] Zero percent for gas dryers accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc.). Eighty-four percent 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, https://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Draft%202%20Version%201.0%20Clothes%20Dryers%20Data%20and%20Analysis.xlsx; 'ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.xlsx'.

3.1.3 Clothes Washer

DESCRIPTION

This measure relates to the installation of a clothes washer meeting the ENERGY STAR® (CEE Tier1), ENERGY STAR® Most Efficient (CEE Tier 2), or CEE Advanced Tier minimum qualifications. If the Domestic Hot Water (DHW) and dryer fuels of the installations are unknown (for example through a retail program), savings are 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 and NC.

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

DEFINITION OF EFFICIENT EQUIPMENT

Clothes washer must meet the ENERGY STAR® (CEE Tier1), ENERGY STAR® Most Efficient (CEE Tier 2), or CEE Advanced Tier minimum qualifications (provided in the table below), 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.[23]

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	

The Integrated Modified Energy Factor (IMEF) includes unit operation, standby, water heating, and drying energy use, with the higher the value the more efficient the unit: "The quotient of the cubic foot (or liter) capacity of the clothes container divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot water energy consumption, the energy required for removal of the remaining moisture in the wash load, and the combined low-power mode energy consumption."

The Integrated Water Factor (IWF) indicates the total water consumption of the unit, with the lower the value the less water required: "The quotient of the total weighted per-cycle water consumption for all 67 wash cycles in gallons divided by the cubic foot (or liter) capacity of the clothes washer."[24]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years.[25]

DEEMED MEASURE COST

The incremental cost assumptions are provided below: [26]

Efficiency Level	Incremental Cost
ENERGY STAR®	$87
ENERGY STAR® Most Efficient/CEE Tier 2	$85
CEE Advanced Tier	$99

[23] DOE Energy Conservation Standards for Clothes Washers, Appliance and Equipment Standard, 10 CFR Part 430.32(g), https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

[24] Definitions provided in ENERGY STAR® v7.1 specification on the ENERGY STAR® website, https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%208.1%20Clothes%20Washer%20Final%20Specificaiton%20-%20Partner%20Commitments%20and%20Eligibility%20Criteria.pdf; 'ENERGY STAR Version 8.1 Clothes Washer Final Specificaiton - Partner Commitments and Eligibility Criteria.pdf'.

[25] Based on DOE Chapter 8 Life-Cycle Cost and Payback Period Analysis, https://www.federalregister.gov/documents/2023/03/03/2023-03862/energy-conservation-program-energy-conservation-standards-for-residential-clothes-washers.

[26] 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
Miscellaneous RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = [(Capacity * 1/IMEFbase * Ncycles) * (%CWbase + (%DHWbase * $\%Electric_{DHW}$)+ (%Dryerbase * $\%Electric_{Dryer}$))]- [(Capacity * 1/IMEFeff * Ncycles) * (%CWeff + (%DHWeff * $\%Electric_{DHW}$) + (%Dryereff * $\%Electric_{Dryer}$))]

Where:

Capacity = Clothes washer capacity (cubic feet)
= Actual - If capacity is unknown, assume 3.45 cubic feet [27]
IMEFbase = Integrated Modified Energy Factor of baseline unit
IMEFeff = Integrated Modified Energy Factor of efficient unit
= Actual.
Ncycles = Number of Cycles per year
= 271[28]
%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)
$\%Electric_{DHW}$ = Percentage of DHW savings assumed to be electric
$\%Electric_{Dryer}$ = Percentage of dryer savings assumed to be electric

Efficiency Level	IMEFbase	
	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft
Federal Standard	1.57	1.84

	Percentage of Total Energy Consumption[29]		
	%CW	%DHW	%Dryer
Federal Standard	6.7%	15.8%	77.5%
ENERGY STAR®, CEE Tier 1	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%

DHW fuel	$\%Electric_{DHW}$
Electric	100%
Natural Gas	0%
Unknown	43%[30]

[27] Based on the average clothes washer volume of all units that pass the new federal standard on the CEC database of clothes washer products (accessed on 08/28/2014).
[28] Weighted average of 271 clothes washer cycles per year (based on 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region for state of Missouri): http://www.eia.gov/consumption/residential/data/2009/. See '2015 Clothes Washer Analysis.xlsx' for details.
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.
[29] 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.
[30] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Missouri.

Dryer fuel	%$Electric_{Dryer}$
Electric	100%
Natural Gas	0%
Unknown	90%[31]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001148238

NATURAL GAS SAVINGS

$\Delta Therms = [[(Capacity * 1/IMEFbase * Ncycles) * ((\%DHWbase * \%Gas_{DHW} * R\_{eff}) + (\%Dryerbase * \%Gas_{Dryer}))] - [(Capacity * 1/IMEFeff * Ncycles) * ((\%DHW * \%Gas_{DHW} * \%Gas_{DHW} * R\_{eff}) + (\%Dryereff * \%Gas_{Dryer}))]] * Therm\_convert$

Where:

$\%Gas_{DHW}$ = Percentage of DHW savings assumed to be natural gas
R_{eff} = Recovery efficiency factor
= 1.26[32]
$\%Gas_{Dryer}$ = Percentage of dryer savings assumed to be natural gas
Therm_convert = Conversion factor from kWh to therm
= 0.03412

Other factors as defined above.

DHW fuel	%Gas_{DHW}
Electric	0%
Natural Gas	100%
Unknown	57%[33]

Dryer fuel	%Gas_{Dryer}
Electric	0%
Natural Gas	100%
Unknown	10%[33]

WATER IMPACT DESCRIPTIONS AND CALCULATION

$\Delta Water = Capacity * (IWF_{base} - IWF_{eff}) * Ncycles$
Where:

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[31] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Missouri, 'HC8.9 Water Heating in Midwest Region.xls'.
[32] 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. Therefore, a factor of 0.98/0.78 (1.26) is applied.
[33] Default assumption for unknown fuel is based EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Missouri.

IWFbase = Integrated Water Factor of baseline clothes washer
= 5.92[34]

IWFeff = Water Factor of efficient clothes washer
= Actual - If unknown assume average values provided below

Other factors as defined above.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[34] Weighted average IWF of Federal Standard rating for front loading and top loading units. Weighting is based upon the relative top vs. front loading percentage of available non-ENERGY STAR® products in the CEC database.

3.1.4 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 (Pints/Day)	ENERGY STAR Criteria (L/kWh)	ENERGY STAR Most Efficient Criteria (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.[35]

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:

Equipment Specification	Population	ENERGY STAR	ENERGY STAR Most Efficient
	Non-IQ	$10[36]	$75[37]

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

[36] 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.

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

Equipment Specification	Population	ENERGY STAR	ENERGY STAR Most Efficient
Portable Dehumidifier	IQ[38]	$35	$100

LOADSHAPE
Cooling RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((((Avg\_Capacity * 0.473) / 24) * Hours) * (IQAdj / (L/kWh\_Base) - 1 / (L/kWh\_Eff))) * ISR$$

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[39]

IQAdj = Baseline consumption adjustment for IQ program participants to account for a portion of participants who would have utilized the secondary market. [40]
= 1.096 if IQ, 1.0 if non-IQ

L/kWh_Base = Baseline liters of water per kWh consumed, as provided in table above.

L/kWh_Eff = Efficient liters of water per kWh consumed. Actual, or if unknown as provided in table above.

ISR = In-service rate.
= Actual.

Annual kWh usage and savings for each capacity class and product type – applicable if actual unit efficiency is unknown – are presented in the tables below. If both unit efficiency and capacity are unknown, apply the average capacity value in the table below.

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[38] IQ Incremental costs factor in the assumption that a secondhand unit costs on average 50% of a new baseline unit, and that 1/3 of IQ participants would have purchased a unit on the secondhand market. The new baseline dehumidifier is assumed to cost $150. See 'IQ Appliance Calculations.xlsx' for information.

[39] 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.

[40] It is assumed that a second-hand unit is on average 1/3 of a measure's EUL years old (8 years). In 2019 a new Federal Standard became effective and "relative to the previous standard, the current standard represents energy savings of about 15-25%". 20% was used, and increased by an estimate of 0.4% * 8 years (based on review of the refrigerator/freezer regression algorithm used in the 5.1.8 Refrigerator and Freezer Recycling measure) to account for degradation of performance over time. This second hand consumption was then weighted 1/3: 2/3 current new baseline to estimate a multiplier for IQ participants. See 'IQ Appliance Calculations.xlsx' for information.

Portable Dehumidifiers				
Capacity Range	Capacity Used[41]	Federal Standard Criteria	ENERGY STAR Criteria	ENERGY STAR Most Efficient
(pints/day)	(pints/day)	(≥ L/kWh)	(≥ L/kWh)	(≥ L/kWh)
≤25	20	1.3	1.57	1.7
>25 and ≤50	37.5	1.6	1.8	1.9
>50 and <155	102.5	2.8	3.3	3.4
Average[42]	38.9	1.54	1.75	1.86

Portable Dehumidifier		Energy Savings (ΔkWh)			
		Non-IQ		IQ	
Capacity Range	Capacity Used	ENERGY STAR	ENERGY STAR Most Efficient	ENERGY STAR	ENERGY STAR Most Efficient
(pints/day)	(pints/day)				
≤25	20	115	157	179	221
>25 and ≤50	37.5	113	160	210	257
>50 and <155	102.5	241	280	392	432
Average	38.9	*134*	*188*	238	293

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

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

[42] 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'.

3.1.5 Refrigerator

DESCRIPTION
A refrigerator meeting either ENERGY STAR®/CEE Tier 1 specifications or the higher efficiency specifications of CEE Tier 2 or CEE Tier 3 is installed instead of a new unit of baseline efficiency. The measure applies to TOS and early replacement programs.

This measure also includes a section accounting for the interactive effect of reduced waste heat on the heating and cooling loads.

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

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

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[43]	ENERGY STAR Maximum Energy Usage in kWh/year[44]
1. Refrigerators and Refrigerator-freezers with manual defrost	Method to measure to estimate existing unit consumption defined below.	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

DEFINITION OF EFFICIENT EQUIPMENT
The high-efficiency level is a refrigerator meeting ENERGY STAR® specifications effective September 15th, 2014 (10% above federal standard), a refrigerator meeting CEE Tier 2 specifications (15% above federal standard), or CEE Tier 3 specifications (20% above federal standards).

DEFINITION OF BASELINE EQUIPMENT
Time of Sale: Baseline efficiency is a new refrigerator meeting the minimum federal efficiency standard for refrigerators.

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

Early Replacement: the baseline is the existing refrigerator for the assumed remaining useful life of the unit and the time of sale baseline as defined above for the remainder of the measure life. Application of early replacement baseline is applicable to low income programs and requires information on pre-existing unit age and configuration.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.[45]

Remaining life of existing equipment is assumed to be 5 years.[46]

DEEMED MEASURE COST

The full cost of a baseline unit is $742.[47]

The incremental cost to the ENERGY STAR® level is $28, to CEE Tier 2 level is $112, and to CEE Tier 3 is $134.[48]

LOADSHAPE

Refrigeration RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Savings will be calculated based on model ENERGY STAR® data, if available. If applicable model ENERGY STAR® data is unavailable, savings by product class may be calculated according to the algorithm below:

Time of sale:

$\Delta kWh_{Unit} = kWh_{base} - kWh_{ee}$

Early replacement:

ΔkWH for remaining life of existing unit (1st 5 years):

$= kWh_{exist} - kWh_{ee}$

ΔkWH for remaining measure life (next 10 years):

$= kWh_{base} - kWh_{ee}$

Where:

kWh_{ee} = Actual. If unknown, calculate by product class:
$= (kWh_{base} * (1 - \%Savings))$

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45 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 35. Based on 2021 DOE Rulemaking Technical Support Document, 'DOE LCC Spreadsheet.xlsm'.

46 Standard assumption of one third of effective useful life.

47 Configurations weighted according to table under Energy Savings. Values inflated 8.9% from 2009 dollars to 2015. Table 8.1.1, DOE, 2011-08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers. https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf; 'refrig_finalrule_tsd.pdf'.

48 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, p. 35. 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 (see 'DOE LCC Spreadsheet.xlsm'). 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.

kWh_{base} = Annual electric energy consumption of baseline unit as calculated in algorithm provided in table above,[49] if new model known; otherwise, assuming 22.5 ft^3 adjusted volume[50] using "all-refrigerators-automatic defrost" formula 8.07AV + 233.7, use value 415.28.

kWh_{exist} = If pre-existing unit age and configuration known: see table below to determine electric energy consumption of pre-existing unit based on unit age and configuration.
If pre-existing unit age and configuration not known: do not apply early replacement baseline.

%Savings = Specification of energy consumption below Federal Standard – see table below.

Tier	%Savings
Energy Star® and CEE Tier 1	10%
Energy Star® Most Efficient and CEE Tier 2	15%
CEE Tier 3	20%

If an early replacement baseline is applicable, the following table may be used to calculate the baseline usage used to calculate savings for the first six years of measure life:

Age	*Bottom Freezer (16 cu ft)*	*Side-by-Side (14 cu ft)*	*Side-by-Side (15 cu ft)*	*Side-by-Side (16 cu ft)*	*Top Freezer (cu ft 14)*	*Top Freezer (15 cu ft)*	*Top Freezer (16 cu ft)*	*Top Freezer (17 cu ft)*	*Top Freezer (18 cu ft)*
2011-2015	483	592	592	592	374	374	374	412	412
2001 (after July-2010	724	747	747	747	556	556	556	613	613
1993-2001(before June)	962	1,139	1,139	1,139	861	861	861	962	962
1990-1992	1,519	1,617	1,617	1,617	1,272	1,272	1,272	1,432	1,432
1980-1989	1,992	2,119	2,119	2,119	1,668	1,668	1,668	1,877	1,877
Before 1980	2,523	2,684	2,684	2,684	2,112	2,112	2,112	2,377	2,377

Additional Waste Heat Impacts

For units in conditioned spaces in the home (if unknown, assume unit is in conditioned space).

$\Delta kWh_{WasteHeat} = \Delta kWh * (WHFeHeatElectric + WHFeCool)$

Where:

ΔkWh = kWh savings calculated from either method above

WHFeHeatElectric = Waste Heat Factor for Energy to account for electric heating increase from removing waste heat from refrigerator/freezer (if fossil fuel heating – see calculation of heating penalty in that section).
= $-(HF / \eta Heat_{Electric}) * \%ElecHeat$

HF = Heating Factor or percentage of reduced waste heat that must now be heated
= 58% for unit in heated space or unknown [51]
= 0% for unit in unheated space

$\eta Heat_{Electric}$ = Efficiency in COP of Heating equipment
= Actual - If not available, use table below:[52]

[49] According to Federal Standard effective 9/15/14.
[50] DOE Building Energy Data Book, https://ieer.org/wp/wp-content/uploads/2012/03/DOE-2011-Buildings-Energy-DataBook-BEDB.pdf; 'DOE-2011-Buildings-Energy-DataBook-BEDB.pdf'
[51] Based on 212 days where HDD 65>0, divided by 365.25.
[52] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 and 2015 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.

%ElecHeat = Percentage of home with electric heat

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[53]	N/A	N/A	1.28

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	35%[54]

WHFeCool = Waste Heat Factor for Energy to account for cooling savings from removing waste heat from refrigerator/freezer.
= CoolF / (ηCool / 3.412) * %Cool

CoolF = Cooling Factor or percentage of reduced waste heat that no longer needs to be cooled
= 40% for unit in cooled space or unknown [55]
= 0% for unit in uncooled space

ηCool = Efficiency in COP of Cooling equipment
= Actual - If not available, see table below

%Cool = Percentage of home with cooling

Age of Equipment	ηCool Estimate
Before 2006	9.5
2006 - 2014	12.4
Central AC After 1/1/2015	12.4
Heat Pump After 1/1/2015	13.3

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91%[56]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{WasteHeatCooling} * CF$$

Where:

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[53] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls ; 'hc6.9.xls'. 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.

[54] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'.

[55] Based on 148 days where CDD 65>0, divided by 365.25.air

[56] Based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region", https://www.eia.gov/consumption/residential/data/2015/hc/php/hc7.9.php.

$\Delta kWh_{WasteHeatCooling}$ = gross customer connected load kWh savings for the measure. Including any cooling system savings.
CF = Summer Peak Coincident Factor
= 0.0001285253[57]

NATURAL GAS SAVINGS

Heating penalty for reduction in waste heat, only for units from conditioned space in gas heated home (if unknown, assume unit is from conditioned space).

$\Delta Therms = \Delta kWh_{Unit} * WHFeHeatGas * 0.03412$

Where:

ΔkWh_{Unit} = kWh savings calculated from either method above, not including the $\Delta kWh_{WasteHeat}$
WHFeHeatGas = Waste Heat Factor for Energy to account for gas heating increase from removing waste heat from refrigerator/freezer
= - (HF / $\eta Heat_{Gas}$) * %GasHeat
HF = Heating Factor or percentage of reduced waste heat that must now be heated
= 58% for unit in heated space or unknown[58]
= 0% for unit in unheated space
$\eta Heat_{Gas}$ = Efficiency of heating system
= 74%[59]
%GasHeat = Percentage of homes with gas heat
0.03412 = Converts kWh to therms

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[60]

Default values for each product class and unknown building characteristics are provided below:

Product Class	ΔTherms		
	Energy Star®/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	-1.19	-1.78	-2.37
Side-by-Side w/ TTD (PC 7)	-1.29	-1.94	-2.58
Bottom Freezer (PC 5)	-1.07	-1.60	-2.13
Bottom Freezer w/ TTD (PC 5A)	-1.41	-2.12	-2.83

If product class is unknown, the following table provides a market weighting that is applied to give a single deemed savings for each efficiency level:

[57] Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors"
[58] Based on 212 days where HDD 65>0, divided by 365.25.
[59] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 52% of Missouri homes - based on Energy Information Administration, 2009 Residential Energy Consumption Survey). Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.
[60] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'.

Product Class	Market Weight[61]	ΔTherms		
		Energy Star®/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	52%	-1.22	-1.84	-2.45
Side-by-Side w/ TTD (PC 7)	22%			
Bottom Freezer (PC 5)	13%			
Bottom Freezer w/ TTD (PC 5A)	13%			

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[61] Personal Communication from Melisa Fiffer, ENERGY STAR® Appliance Program Manager, EPA 10/26/14.

3.2 Electronics

3.2.1 Advanced Tier 1 Power Strips

DESCRIPTION

This measure applies to Tier 1 Advanced Power Strips (APS), which are multi-plug power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a master control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the master 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 are always providing power to any device plugged into it. This measure characterization provides savings for use of an APS in a home entertainment system, home office, or unknown setting.

This measure was developed to be applicable to the following program types: TOS, NC, DI, and 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 4-8 plug Tier 1 master-controlled APS.

DEFINITION OF BASELINE EQUIPMENT

For TOS and NC applications, the baseline is a standard power strip that does not control connected loads.
For DI and KITS, the baseline is the existing equipment used in the home.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the Tier 1 APS is 10 years.[62]

DEEMED MEASURE COST

For TOS and NC, the incremental cost of an APS over a standard power strip with surge protection is assumed to be $20.[63]
For DI and KITS, the actual full installation cost of an APS (including equipment and labor) should be used. If DI cost is unknown, cost is assumed to be $30.00. [64]

LOADSHAPE

Miscellaneous RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (kWh_{Office} * Weighting_{Office} + kWh_{Ent} * Weighting_{Ent}) * ISR$$

Where:

kWh_{Office} = Estimated energy savings from using an APS in a home office

[62] "Advanced Power Strip Research Report," NYSERDA, August 2011, https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/EERP/Residential/Power-Management-Research-Report.pdf; 'NYSERDA Advanced Power Strip Research Report.pdf', page 30
[63] Incremental cost based on "Advanced Power Strip Research Report." https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/EERP/Residential/Power-Management-Research-Report.pdf; 'NYSERDA Advanced Power Strip Research Report.pdf',page 6. Typical cost of an advanced power strip is $35, and average cost of a standard power strip is $15.
[64] Ibid.

= 31.0 kWh[65]

$Weighting_{Office}$ = Relative penetration of use in home office

Installation Location	$Weighting_{Office}$
Home Office	100%
Home Entertainment System	0%
Unknown[66]	TOS, NC, DI: 36% KITS: 48%

kWh_{Ent} = Estimated energy savings from using an APS in a home entertainment system
= 75.1 kWh[67]

$Weighting_{Ent}$ = Relative penetration of use with home entertainment systems

Installation Location	$Weighting_{Ent}$
Home Office	0%
Home Entertainment System	100%
Unknown[68]	TOS, NC, DI: 64% KITS: 52%

ISR = In-service rate. Actual, or if unknown, reference values in the table below dependent on program type

Program Type	ISR
TOS, NC, DI[69]	95%
KITS[70]	93.8%
Pay As You Save[71]	74.3%

Based on the default values above, default savings are provided in the table below:

Installation Location	Program Type	ΔkWh
Home Office	TOS, NC, DI	29.45
	KITS	29.08
Home Entertainment System	TOS, NC, DI	71.35
	KITS	70.44
Unknown	TOS, NC, DI	56.26
	KITS	50.59

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Electric energy savings, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

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65 "Advanced Power Strip Research Report." https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/EERP/Residential/Power-Management-Research-Report.pdf; 'NYSERDA Advanced Power Strip Research Report.pdf'. Note that estimates are not based on pre/post metering but on analysis based on frequency and consumption of likely products in active, standby, and off modes. This measure should be reviewed frequently to ensure that assumptions continue to be appropriate.

66 Relative weightings of home office and entertainment systems is based on "Ameren Missouri Efficient Product Impact and Process Evaluation: Program Year 2015," Cadmus, May 13, 2016. https://www.efis.psc.mo.gov/Document/Display/13805, page 34. If the programs have their own evaluations of weightings, they should be used.

67 "Advanced Power Strip Research Report." https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/EERP/Residential/Power-Management-Research-Report.pdf; 'NYSERDA Advanced Power Strip Research Report.pdf'.

68 Relative weightings of home office and entertainment systems is based on "Ameren Missouri Efficient Product Impact and Process Evaluation: Program Year 2015," Cadmus, May 13, 2016, https://www.efis.psc.mo.gov/Document/Display/13805, page 34. If the programs have their own evaluations of weightings, they should be used.

69 Ameren Missouri Single Family Low Income Evaluation: PY2019, Table 10-10, https://www.efis.psc.mo.gov/Document/Display/15877, page 214.

70 Ameren Missouri Efficient Products Evaluation: PY2019, Table 6-9, https://www.efis.psc.mo.gov/Document/Display/15877, page 140 .

71 Ameren Missouri Pay As You Save (PAYS®) Evaluation Appendices: PY2022, https://www.efis.psc.mo.gov/Document/Display/17591, page 7.

= 0.0001148238[72]

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[72] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors"for residential miscellaneous end-use. This is deemed appropriate, because savings occur during hours when the controlled standby loads are turned off by the APS. This is estimated to be approximately 7,129, which representing the average of hours for controlled TV and computer from "Advanced Power Strip Research Report.", https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/EERP/Residential/Power-Management-Research-Report.pdf; 'NYSERDA Advanced Power Strip Research Report.pdf'.

3.2.2 Tier 2 Advanced Power Strip – 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.[73] 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'.

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, one being the television.[74]

DEFINITION OF BASELINE EQUIPMENT

The assumed baseline equipment is the existing equipment 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 assumed lifetime of the Tier 2 AV APS is assumed to be 10 years.[75]

DEEMED MEASURE COST

Direct Install: The actual installed cost (including labor) of the new Tier 2 AV APS equipment should be used, less baseline cost of $20.[76]
For non-direct install, incremental cost is assumed to be $65.[77]

LOADSHAPE

Miscellaneous RES

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.

[73] 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.
[74] Given this requirement, an AV environment consisting of a TV and DVD player or a TV and home theater would be eligible for a Tier 2 AV APS installation.
[75] "Advanced Power Strip Research Report," NYSERDA, August 2011, https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/EERP/Residential/Power-Management-Research-Report.pdf; 'NYSERDA Advanced Power Strip Research Report.pdf', page 30.
[76] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 93. Price survey performed by Illume Advising LLC for IL TRM workpaper, see 'Current Surge Protector Costs and Comparison 7-2016.xlsx' spreadsheet
[77] California Technology Forum, June 2015. https://static1.squarespace.com/static/53c96e16e4b003bdba4f4fee/t/556e25a3e4b06957271187a1/1433281955286/2015-01-15+Tier+2+Advance+Power+Strip+Cal+TF+Workpaper+Presentation_January.pdf; 'Tier_2_Advance_Power_Strip_Cal_TF_Workpaper_01.2015.pdf'.

Product Type	ERP used
Infrared Only	40%[78]
Infrared and Occupancy Sensor	25%[79]

$BaselineEnergy_{AV}$ = 466 kWh[80]

ISR = In Service Rate, the percentage of units rebated that are actually in service. Actual, or if unknown, referencing the table below:

Program/Channel	In Service Rate (ISR)
TOS, NC, DI[81]	95%
Efficient Kits[82]	93.8%
SF Low Income Kits[83]	93.8%

Based on the default values above, default savings are provided in the table below:

Program Type	ΔkWh	
	Infrared Only	Infrared and Occupancy Sensor
TOS, NC, DI	177.08	110.68
Efficient Kits	174.84	109.28
SF Low Income Kits	174.84	109.28

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

[78] 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%).

[79] 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%)

[80] "Energy Savings of Tier 2 Advanced Power Strips in Residential AV Systems," AESC, Inc., February 2016. Note this load represents the average *controlled* AV devices only and will likely be lower than total AV usage, https://www.aesc-inc.com/wp-content/uploads/2017/07/tier_2_aps_final_report_et13pge1441.pdf; 'tier_2_aps_final_report_et13pge1441.pdf', page 7.

[81] Ameren Missouri Single Family Low Income Program Evaluation: PY2019, Table 10-10, https://www.efis.psc.mo.gov/Document/Display/15877, page 214.

[82] Ameren Missouri Efficient Products Program Evaluation: PY2019, Table 6-9, https://www.efis.psc.mo.gov/Document/Display/15877, page 140.

[83] Assume same as Efficient Kits.

= 0.0001148238[84]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[84] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for residential miscellaneous end-use. This is deemed appropriate, as savings occur during hours which the controlled standby loads are turned off by the APS, estimated to be approximately 7,129 representing the average of hours for controlled TV and computer from "Advanced Power Strip Research Report.", https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/EERP/Residential/Power-Management-Research-Report.pdf; 'NYSERDA Advanced Power Strip Research Report.pdf'.

3.3 Hot Water

3.3.1 Low Flow Faucet Aerator

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, and 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 2.25 GPM or greater or a standard kitchen faucet aerator rated at 2.75 GPM or greater. Average measured flow rates are used in the algorithm and are lower, reflecting the penetration of previously installed low flow fixtures, 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.[85]

DEEMED MEASURE COST

The incremental cost for this measure is $11.33[86] or actual cost.

For faucet aerators provided in efficiency kits, the actual program delivery costs should be utilized. Absent of program data, for efficiency kits reference cost of $3.00.[87]

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[88] (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 * (1 – Leakage)

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	42%[89]

[85] ComEd Effective Useful Life Research Report, Navigant, May 14, 2018, . https://www.icc.illinois.gov/docket/P2017-0312/documents/287811/files/501915.pdf; 'ComEd Effective Useful Life Research Report.pdf', page 20.
[86] Direct-install price per showerhead assumes cost of showerhead (market research average of $3 and assess and install cost of $8.33) and also assumes 20min at $25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor.
[87] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 259.
[88] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.
[89] Ameren Missouri Energy Efficient Kits Impact and Process Evaluation: PY2019 https://www.efis.psc.mo.gov/Document/Display/15876, page 72.

GPM_{base} = Average flow rate, in gallons per minute, of the baseline faucet "as-used." This includes the effect of existing low flow fixtures.
= 2.2[90] or custom based on metering studies[91] or if measured during DI:
= Measured full throttle flow * 0.83 throttling factor[92]

GPM_{low} = Average flow rate, in gallons per minute, of the low-flow faucet aerator "as-used"
= 1.5[93] or custom based on metering studies[94] or if measured during DI:
= Rated full throttle flow * 0.95 throttling factor[95]

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	Bathroom
Efficient Kits (School Kits, MF, ARP Kits)	4.5[96]	1.6[97]
Income Eligible; MFMR, PAYS, Efficient Kits (SFLI Kits)[98]	3.7	3.7
If location unknown (total for household): Single-Family	7.8[99]	
If location unknown (total for household): Multi-Family	6.7[100]	

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	Bathroom
Efficient Kits (School Kits, ARP Kits)	4.5[101]	1.6[102]
Income Eligible; MFMR, PAYS, Efficient Kits (SFLI Kits)[103]	3.7	3.7
If location unknown (total for household): Single-Family	7.8[104]	
If location unknown (total for household): Multi-Family	6.7[105]	

[90] Federal rated maximum flow rate for faucets, https://www.energy.gov/femp/best-management-practice-7-faucets-and-showerheads.
[91] Measurement should be based on actual average flow consumed over a period of time rather than a one-time 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.
[92] 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, pp. 1-265. https://map-testing.com/wp-content/uploads/2022/11/2008_Seattle_Study.pdf; '2008_Seattle_Study.pdf'.
[93] Program data, including PY2016 Program Data, per Community Savers 2016 EM&V report. https://www.efis.psc.mo.gov/Document/Display/35141, page 3-8.
[94] Measurement should be based on actual average flow consumed over a period of time rather than a one-time 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.
[95] 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, pp. 1-265. https://map-testing.com/wp-content/uploads/2022/11/2008_Seattle_Study.pdf; '2008_Seattle_Study.pdf'.
[96] 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.
[97] 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.
[98] Cadmus PY11 metering study. Cited in Ameren Missouri Low Income and Process Evaluation: program Year 2015. p.23 https://www.efis.psc.mo.gov/Document/Display/12018
[99] One kitchen faucet plus 2.04 bathroom faucets. Based on findings from a 2012 Ameren Missouri potential study for single family homes.
[100] One kitchen faucet plus 1.4 bathroom faucets. Based on findings from Ameren Missouri PY2013 data for multifamily homes.
[101] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[102] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[103] Cadmus PY11 metering study. Cited in Ameren Missouri Low Income and Process Evaluation: program Year 2015. p.23 https://www.efis.psc.mo.gov/Document/Display/12018
[104] One kitchen faucet plus 1.4 bathroom faucets. Based on findings from an Ameren Missouri PY2013 data for multifamily homes.
[105] One kitchen faucet plus 1.4 bathroom faucets. Based on findings from an Ameren Missouri PY2013 data for multifamily homes.

Household = Average number of people per household

Program Delivery and Household Unit Type	Value
Single-Family	2.67[106]
School Kits	4.286[107]
Efficient Kits (MF)	1.777[108]
Multi-Family MR	1.56[109]
Income Eligible, Efficient Kits (SFLI Kits), PAYS	1.564[110]
ARP Kits	2.65[111]
Custom	Actual Occupancy or Number of Bedrooms[112]

365.25 = Days in a year, on average.

DF = Drain Factor

Program Delivery	Drain Factor	
	Kitchen	Bath
Non SFLI Kits[113]	75%	90%
Income Eligible, MFMR, SFLI Kits, PAYS[114]	100%	100%
Unknown	79.5%	N/A

FPH = Faucets Per Household

Program Delivery	FPH	
	Kitchen (KFPH)	Bathroom (BFPH)
Single-Family	1.19[115]	2.04[116]
School Kits	1.19[117]	2.28[118]
Efficient Kits (MF)	1.00[119]	1.337[120]
Multi-Family (MFMR), PAYS	1.00[121]	1.86[122]
Income Eligible, Efficient Kits (SFLI Kits)	1.00	1.86[123]
If location unknown (total for household): Single-Family	3.04	
If location unknown (total for household): Multi-Family	2.4	

EPG_electric = Energy per gallon of water used by faucet supplied by electric water heater
= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

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[106] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus. https://www.efis.psc.mo.gov/Document/Display/13805, page 36
[107] Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 72.
[108] PY2018 Energy Efficiency Kits Property Manager Survey results (I1-I2), https://www.efis.psc.mo.gov/Document/Display/15870, page 34.
[109] Ameren Missouri Community Savers Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/36053.
[110] PY2006 program data (not reported in PY2016).
[111] Ameren Missouri Appliance Recycling Program Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 91.
[112] 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.
[113] Because faucet usages are at times dictated by volume (e.g., filling a cooking pot), 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 recommends 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.
[114] Ameren Missouri Community Savers Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/36053.
[115] Ameren Missouri Energy Efficient Kits Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 34.
[116] Based on findings from a 2012 Ameren Missouri potential study for single family homes.
[117] Ameren Missouri Energy Efficient Kits Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 34.
[118] Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 36.
[119] Ameren Missouri EE Kits PY2018 Program Data, https://www.efis.psc.mo.gov/Document/Display/15870, page 34
[120] Ameren Missouri Energy Efficient Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 36.
[121] Ameren Missouri EE Kits PY2018 Program Data, https://www.efis.psc.mo.gov/Document/Display/15870, page 34.
[122] Ameren Missouri Community Savers Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/36053, page 23.
[123] Ameren Missouri Community Savers Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/36053, page 23.

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 Bathroom (80F for Income Eligible, PAYS and MFMR), 93F for Kitchen, 91F for Unknown[124]
SupplyTemp = Assumed temperature of water entering house
= 58.4F[125]
RE_electric = Recovery efficiency of electric water heater
= 98%[126]
3,412 = Converts Btu to kWh (btu/kWh)
ISR = In-service rate. Actual, or if unknown, reference applicable assumed value in the table below:

Selection	In-Service Rate	
	Kitchen	Bathroom
Direct Install, Efficiency Kit—Low Income[127]	89%	89%
Efficiency Kit (School)—Single Family[128]	40%	48%
Efficiency Kit—Appliance Recycling[129]	20%	24%
Efficiency Kit (School)—Multi Family[130]	100%	100%
Income Eligible, Direct Install (Income Eligible and MFMR)[131]	95%	95%
Income Eligible, Non-Direct Install[132]	40%	48%
Income Eligible, Common Area	N/A	97.7%
Pay As You Save[133]	80.9%	80.9%

Leakage = Percent homes outside service territory

Program	Leakage
School Kits	28%[134]
Other Programs	0%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh * CF

Where:

ΔkWh = as calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0000887318[135]

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[124] 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.
[125] National Weather Service. Average soil temperature at 40" depth during 2015 - 2023 data of six stations in Ameren Missouri service territory. https://www.weather.gov/ncrfc/LMI_SoilTemperatureDepthMaps.
[126] Electric water heaters have recovery efficiency of 98%: NREL Building America Research Benchmark Definition, December 2009, page 12, https://www.nrel.gov/docs/fy10osti/47246.pdf.
[127] Ameren Missouri Single Family Low Income Evaluation PY2019 (Table 10-10), https://www.efis.psc.mo.gov/Document/Display/15877, page 214.
[128] Ameren Missouri Efficient Kits Impact and Process Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15877, page 154.
[129] Ameren Missouri Appliance Recycling Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15877, page 179.
[130] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015, https://www.efis.psc.mo.gov/Document/Display/13805.
[131] Ameren Missouri Community Savers Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/36053, page 23.
[132] Ameren Missouri Efficient Kits Impact and Process Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15877, page 154.
[133] Ameren Missouri Pay As You Save (PAYS®) Evaluation: PY2022 Participant Survey, https://www.efis.psc.mo.gov/Document/Display/17591, page 7.
[134] PY2018 Energy Efficiency Kits School Evaluation Report, page 74.
[135] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for residential water heating end-use.

NATURAL GAS SAVINGS

ΔTherms = %GasDHW * (GPM_{base} * $L_{\_base}$ - GPM_{low} * L_{low}) * Household * 365.25 *DF / FPH * EPG_gas * ISR * (1 – Leakage)

Where:

%GasDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	%GasHW
Electric	0%
Natural Gas	100%
Unknown	48%[136]

EPG_gas = Energy per gallon of Hot water supplied by gas
= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)

RE_gas = Recovery efficiency of gas water heater
= 78% For SF homes[137]
= 67% For MF homes[138]

100,000 = Converts Btus to therms (btu/therm)

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔGallons = ((GPM_{base} * $L_{\_base}$ - GPM_{low} * L_{low}) * Household * 365.25 *DF / FPH) * ISR * (1 – Leakage)

Variables as defined above.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[136] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Missouri, 'HC8.9 Water Heating in Midwest Region.xls'.

[137] 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%.

[138] 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.

3.3.2 Low Flow Showerhead

DESCRIPTION
This measure relates to the installation of a low flow showerhead in a single or multifamily household.

This measure may be used for units provided through efficiency kit's. 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, and 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, typically rated at 2.0 gallons per minute (GPM) or less. Savings are calculated on a per showerhead fixture basis.

DEFINITION OF BASELINE EQUIPMENT
For DI programs, the baseline condition is assumed to be a standard showerhead rated at 2.5 GPM[139] or greater.
For RF and TOS 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 10 years.[140]

DEEMED MEASURE COST
The incremental cost for TOS, NC, or KITS is $7[141] for standard showerheads and $15.02 for handheld showerheads or program actual.

For low flow showerheads provided in RF or DI programs, the actual program delivery costs should be utilized; if unknown assume $15.33[142] for standard showerheads and $23.35 for handheld showerheads.

LOADSHAPE
Water Heating RES

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 * (1 – Leakage)

Where:
%ElectricDHW = proportion of water heating supplied by electric resistance heating

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[139] Maximum showerhead flow rate at 80 PSI is 2.5 GPM in accordance with federal standard 10 CFR Part 430.32(p). See docket filed at https://www.regulations.gov/document?D=EERE-2011-BT-TP-0061-0039
[140] 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, https://www.caetrm.com/media/reference-documents/HVAC_Ltg_measure_life_GDS_2007.pdf; 'HVAC_Ltg_measure_life_GDS_2007.pdf', page C-6
[141] Based on online pricing market research 2/6/2017.
[142] Direct-install price per showerhead assumes cost of showerhead (market research average of $7) and also assumes assess and install cost of $8.33 (20min at $25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor).

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	42%[143]

GPM_{base} = Flow rate of the baseline showerhead

Program Delivery	GPM_base
Direct-install, SFLI Kits	2.2[144]
Retrofit, Efficiency Kits, NC or TOS	2.35[145]
MFMR	2.5[146]

GPM_{low} = As-used flow rate of the lowflow showerhead[147], which may, as a result of measurements of program evaulations deviate from rated flows. If the as-used flow rate is not available, the rated flow rate should be applied.

L_{base} = Shower length in minutes with baseline showerhead
= 7.8 min[148] and 8.66 for Income Eligible, MFMR, SFIE Kits[149]

L_{low} = Shower length in minutes with low-flow showerhead
= 7.8 min[150] and 8.66 for Income Eligible, MFMR, SFIE Kits[151]

Household = Average number of people per household

Program Delivery	Household
Single-Family TOS, Income Eligible (SFIE Kits)	2.67[152]
School Kits	4.29[153]
Efficient Kits (MF)	1.777[154]
Income Eligible Multi-Family, PAYS Multi-Family	1.52[155]
Appliance Recycling Kits	2.65[156]
Multi-Family TOS, MFMR	2.07[157]
Custom	Actual Occupancy or Number of Bedrooms[158]

SPCD = Showers Per Capita Per Day

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[143] Ameren Missouri Energy Efficient Kits Impact and Process Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 73.
[144] Ameren Missouri Community Savers Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/36053.
[145] IL TRM v12.0, Volume 3, page 271, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf.
[146] PY2019 Program Data, https://www.efis.psc.mo.gov/Document/Display/15876, page 86.
[147] 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.
[148] 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.
[149] DeOreo, William, P. Mayer, L. Martien, M. Hayden, A. Funk, M. Kramer-Duffield, and R. Davis (2011). "California Single Family Water Use Efficiency Study.", https://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/byron_bethany/docs/exhibits/pt/wr71.pdf; 'California Single Family Water Use Study.pdf', page 91.
[150] 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.
[151] DeOreo, William, P. Mayer, L. Martien, M. Hayden, A. Funk, M. Kramer-Duffield, and R. Davis (2011). "California Single Family Water Use Efficiency Study.", https://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/byron_bethany/docs/exhibits/pt/wr71.pdf; 'California Single Family Water Use Study.pdf', page 91.
[152] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus, https://www.efis.psc.mo.gov/Document/Display/13805, page 38.
[153] Ameren Missouri Energy Efficient Kits Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 74.
[154] PY2018 Energy Efficiency Kits Property Manager Survey results (I1-I2), https://www.efis.psc.mo.gov/Document/Display/15870, page 32.
[155] Ameren Missouri Community Savers Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/36053, page 39.
[156] Ameren Missouri Appliance Recycling Evaluation PY2019 (Appendix Table 55), https://www.efis.psc.mo.gov/Document/Display/15876, page 92.
[157] Matches PY2015 Community Savers EM&V, https://www.efis.psc.mo.gov/Document/Display/13809, page 20.
[158] Bedrooms are suitable proxies for household occupancy and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

= 0.832[159] and 0.66 for Income Eligible, MFMR, SFIE Kits, and PAYS[160]

365.25 = Days per year, on average.

SPH = Showerheads Per Household so that per-showerhead savings fractions can be determined

Program Delivery	SPH
Single-Family, Income Eligible (SFIE Kits)	2.05[161]
School Kits	2.14[162]
Efficient Kits (MF)	1.34[163]
Income Eligible Multi-Family, PAYS Multi-Family	1.0[164]
MFMR	1.4[165]
Custom	Actual

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 – 60.83)) / (0.98 * 3412)

= 0.100 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

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

ShowerTemp = Assumed temperature of water

= 105.0 F[166]

SupplyTemp = Assumed temperature of water entering house

= 58.4F[167]

RE_electric = Recovery efficiency of electric water heater

= 98%[168]

3,412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Actual, or if unknown, reference applicable assumed value in the table below:

Program Delivery	ISR
Direct Install[169]	100%
Efficiency Kit—School (Single Family)[170]	54%
Efficiency Kit—Multifamily[171]	100%
Efficiency Kit—Appliance Recycling[172]	24%
Income Eligible (Single Family Direct Install) [173]	94%
Income Eligible (Multifamily Direct Install), MFMR Direct Install[174]	96.4%

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[159] Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 74.

[160] DeOreo, William, P. Mayer, L. Martien, M. Hayden, A. Funk, M. Kramer-Duffield, and R. Davis (2011). "California Single Family Water Use Efficiency Study", https://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/byron_bethany/docs/exhibits/pt/wr71.pdf; 'California Single Family Water Use Study.pdf'.

[161] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus, https://www.efis.psc.mo.gov/Document/Display/12014, page 38.

[162] Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 74.

[163] Ameren Missouri PY2018 EE Kits Evaluation, https://www.efis.psc.mo.gov/Document/Display/15870, page 32.

[164] Ameren Missouri Community Savers Evaluation: PY2017, https://www.efis.psc.mo.gov/Document/Display/36053, page 22.

[165] Ameren Missouri Efficient Products Impact and Process Evalluation: Planning Year 2015, page 38, https://www.efis.psc.mo.gov/Document/Display/12014

[166] Ameren Missouri Efficient Kits Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 32.

[167] National Weather Service. Average soil temperature at 40" depth during 2015 - 2023 data of six stations in Ameren Missouri service territory. https://www.weather.gov/ncrfc/LMI_SoilTemperatureDepthMaps.

[168] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx.

[169] Ameren Missouri Community Savers Tenant Surveys and Site Visits PY2017, https://www.efis.psc.mo.gov/Document/Display/28281.

[170] Ameren Missouri Efficient Kits Impact and Process Evaluation: PY2019, Table 7-10, https://www.efis.psc.mo.gov/Document/Display/15877, page 154.

[171] Ameren Missouri PY2018 EE Kits Evaluation, https://www.efis.psc.mo.gov/Document/Display/15870, page 32.

[172] Ameren Missouri Appliance Recycling Evaluation: PY2019, Table 9-10, https://www.efis.psc.mo.gov/Document/Display/15877, page 186.

[173] Ameren Missouri Single Family Low Income Evaluation PY2019 (Table 10-10), https://www.efis.psc.mo.gov/Document/Display/15877, page 214.

[174] Ameren Missouri Community Savers Evaluation PY2018 Tenant Surveys and Site Visits, https://www.efis.psc.mo.gov/Document/Display/36053, page 22.

Program Delivery	ISR
Income Eligible (Non-Direct Install), MFMR (Non-Direct Install), SFLI Kits[175]	91.3%
Pay As You Save[176]	65%

3,412 = Converts Btu to kWh (btu/kWh)
Leakage = Percent homes outside service territory

Program	Leakage
School Kits	28%[177]
Other Programs	0%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = as calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0000887318[178]

NATURAL GAS SAVINGS

$\Delta Therms = \%GasDHW * ((GPM_{base} * L_{base} - GPM_{low} * L_{low}) * Household * SPCD * 365.25 / SPH) * EPG\_gas * ISR * (1 – Leakage)$

Where:

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

DHW fuel	%GasDHW
Electric	0%
Natural Gas	100%
Unknown	48%[179]

EPG_gas = Energy per gallon of Hot water supplied by gas
= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)
= 0.00429 therm/gal for SF homes
= 0.00499 therm/gal for MF homes
RE_gas = Recovery efficiency of gas water heater
= 78% For SF homes[180]
= 67% For MF homes[181]
100,000 = Converts Btus to therms (btu/Therm)
Other variables as defined above.

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[175] PY2017 CommunitySavers Report, page 3-7, https://www.efis.psc.mo.gov/Document/Display/28281.
[176] Ameren Missouri Pay As You Save (PAYS®) Evaluation: PY2022 Participant Survey, https://www.efis.psc.mo.gov/Document/Display/17591, page 7.
[177] PY2018 Energy Efficiency Kits School Evaluation Report, https://www.efis.psc.mo.gov/Document/Display/15870, page 74.
[178] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for residential water heating end-use.
[179] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Missouri, 'HC8.9 Water Heating in Midwest Region.xls'.
[180] 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. However, these numbers represent the range of new units, 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%.
[181] 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

ΔGallons = $((GPM_{base} * L_{base} - GPM_{low} * L_{low}) * Household * SPCD * 365.25 / SPH) * ISR * (1 – Leakage)$

Variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

3.3.3 Heat Pump Water Heater

DESCRIPTION

This measure applies to the installation of a heat pump water heater (HPWH) in place of a standard electric water heater in a home. Savings are presented dependent on the heating system installed in the home due to the impact of the heat pump water heater on the heating and cooling loads.

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

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 water heater with a storage volume ≤ 55 gallons.[182]

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a new, electric storage water heater meeting federal minimum efficiency standards[183] for units ≤55 gallons:

Draw Pattern	Federal Standard – Uniform Energy Factor[184]
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)

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

If unknown, assume a 50 gallon resistance tank baseline, at medium draw, therefore 0.9207 UEF. [185]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.[186]

DEEMED MEASURE COST

Actual costs should be used where available. Default incremental cost values are provided in the table below.[187]

Efficiency Range	Baseline Installed Cost	Efficient Installed Cost	Incremental Installed Cost
<2.6 UEF	$1,032	$2,062	$1,030
≥2.6 UEF	$1,032	$2,231	$1,199

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = [(((1/EF_{BASE} - 1/EF_{EE}) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{In}) * 1.0)) / 3,412) + kWh_{cool} - kWh_{heat}] * ISR$

[182] Since the federal standard effectively requires a heat pump water heater for units over 55 gallons, this measure is limited to units ≤ 55 gallons.
[183] Minimum federal standard up to date as of 8/15/2024: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430; '10 CFR Part 430 (up to date as of 8-15-2024).pdf'.
[184] 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.
[185] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 249.
[186] 2010 Residential Heating Products Final Rule Technical Support Document, U.S. DOE, Table 8.7.2.
[187] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, p. 250. Costs for <2.6 UEF are based upon averages from the NEEP Phase 3 Incremental Cost Study ('NEEP Incremental Cost Study FINAL_061016.pdf'). The assumption for higher efficiency tanks is based upon averaged from NEEP Phase 4 Incremental Cost Study.

Where:

UEF_{BASE} = UEF of standard electric water heater according to federal standards
= If new unit draw pattern unknown, 0.9207[188].

UEF_{EE} = UEF of heat pump water heater
= Actual

GPD = Gallons per day of hot water use per person
= 17.6[189]

Household = Average number of people per household

Household Unit Type[190]	Household
Single-Family - Deemed	2.65[191]
Multi-Family - Deemed	2.07[192]
Custom	Actual Occupancy or Number of Bedrooms[193]

365.25 = Days per year
γWater = Specific weight of water
= 8.33 pounds per gallon
T_{OUT} = Tank temperature
= Actual, if unknown assume 125°F
T_{IN} = Incoming water temperature from well or municipal system
= 58.4F[194]
1.0 = Heat capacity of water (1 Btu/lb*°F)
3,412 = Conversion factor from Btu to kWh
ISR = In-service rate. Actual, or if unknown, assume 100%[195]
kWh_cool = Cooling savings from conversion of heat in home to water heat[196]
$= [(((1- 1/UEF_{EE}) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{In}) * 1.0) * LF * WHF_C * LM) / (COP_{COOL} * 3{,}412)] * \%Cool$

Where:

LF = Location Factor
= 1.0 for HPWH installation in a conditioned space
= 0.0 for installation in an unconditioned space
= 0.81 if unknown[197]
WHF_C = Portion of reduced waste heat that results in cooling savings (if unknown, assume 53%) [198]
COP_{COOL} = COP of central air conditioner

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188 Federal Register :: Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters
189 GPD based on 45.5 gallons of hot water per day per household and 2.59 people per household, from "Residential End Uses of Water Study 2013 Update," by Deoreo, B., and P. Mayer, for the Water Research Foundation, 2014, https://www.awwa.org/Portals/0/AWWA/ETS/Resources/WaterConservationResidential_End_Uses_of_Water.pdf; 'WaterConservationResidential_End_Uses_of_Water.pdf'.
190 If household type is unknown, as may be the case for TOS measures, then single family deemed value shall be used.
191 Ameren Missouri Efficient Products Evaluation: PY2018, https://www.efis.psc.mo.gov/Document/Display/15869, page 32.
192 Ameren Missouri Efficient Products Evaluation: PY2015, https://www.efis.psc.mo.gov/Document/Display/13805, page 36.
193 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.
194 National Weather Service. Average soil temperature at 40" depth during 2015 - 2023 data of six stations in Ameren Missouri service territory. https://www.weather.gov/ncrfc/LMI_SoilTemperatureDepthMaps.
195 Ameren Missouri Efficient Products Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15877, page 140.
196 This algorithm calculates the heat removed from the air by subtracting the heat pump water heater electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the heat pump unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling, and latent cooling demands.
197 Wisconsin Focus on Energy 2023 Technical Reference Manual, https://assets.focusonenergy.com/production/inline-files/Focus_on_Energy_2023_TRM.pdf, page 787.
198 Based on Ameren Missouri Efficient Products Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/15869, page 32.

= Actual, or if unknown, assume 2.8 COP[199]

LM = Latent multiplier to account for latent cooling demand [200]

Weather Basis (City based upon)	LM
St. Louis, MO	1.33

%Cool = Percentage of homes with central cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	95%[201]

kWh_heat = Heating cost from conversion of heat in home to water heat (dependent on heating fuel)
= [(((1- 1/UEF_EE) * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{In}) * 1.0) * LF * WHF_H *LM) / (COP_{HEAT} * 3,412)] * %ElectricHeat

Where:

WHF_H = Portion of reduced waste heat that results in increased heating load (if unknown, assume 43%) [202]

COP_{HEAT} = COP of electric heating system
= Actual, or if unknown, assume:

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[203]	N/A	N/A	1.28

%ElectricHeat = Percentage of homes with electric heat

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[204]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh * CF

Where:

[199] Starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * $SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003), "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations," (Masters thesis), University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP.

[200] The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads. The values are derived from the methodology outlined in "Infiltration Factor Calculation Methodology" by Bruce Harley, Senior Manager, Applied Building Science, CLEAResult 11/18/2015, and are based upon an 8760 analysis of sensible and total heat loads using hourly climate data. (Ameren Missouri Efficient Products Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/15869, page 32)

[201] Ameren Missouri PY2019 Residential Baseline Study (Saturation of non-low income homes with central cooling).

[202] Based on Ameren Missouri Efficient Products Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/15869, page 31.

[203] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls ; 'hc6.9.xls'. 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.

[204] Average (default) value of 35% electric space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

ΔkWh = Electric energy savings, as calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0000887318[205]

[205] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for residential water heating end-use.

NATURAL GAS SAVINGS

ΔTherms = [(((1- 1/EF_EE) * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{In}) * 1.0) * LF * 0.43) / (ηHeat * 100,000)] * %GasHeat

Where:

ΔTherms = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat[206]

100,000 = Conversion factor from Btu to therms

ηHeat = Efficiency of heating system

= 71%[207]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[208]

Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[206] 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. The variable 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.

[207] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). See reference https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls ; 'hc6.9.xls'. In 2000, 29% of furnaces purchased in Missouri 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 15 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

[208] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'.

3.3.4 Hot Water Pipe Insulation

DESCRIPTION

This measure applies to the addition of insulation to uninsulated domestic hot water (DHW) pipes. The measure assumes the pipe wrap is installed on the first length of both the hot and cold pipes up to the first elbow or the first three feet of pipe length, whichever is longer. This is the most cost-effective section to insulate since, close to the tank, the water pipes act as an extension of the hot water tank, which acts as a heat trap. Insulating this section helps to reduce standby losses.

This measure was developed to be applicable to the following program types: DI, and RF

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is a domestic hot or cold water pipe with pipe wrap installed that has an R value that meets program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is an uninsulated, domestic hot or cold water pipe.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[209]

DEEMED MEASURE COST

The measure cost is the actual cost of material and installation. If the actual cost is unknown, for a kit program, assume a default cost of $2.87.[210]; otherwise, assume a default cost of $7.10 [211] per linear foot, including material and installation.

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below for electric systems, otherwise assume 24.7 kWh per 6 linear feet of ¾ in, R-4 insulation or 35.4 kWh per 6 linear feet of 1 in, R-6 insulation:

$\Delta kWh = \%ElectricDHW * ((C_{Base}/R_{Base} – C_{EE}/R\_{EE}) * L * \Delta T * Hours)/(\eta DHW_{Elec} * 3,412) * ISR * (1 – Leakage)$

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	42%[212]

C_{Base} = Circumference (ft) of uninsulated pipe
= Diameter (in) * π/12
= Actual or, if unknown, assume 0.144” based on a weighted average of 80% 0.50-inch diameter pipe and 20% 0.75-inch diameter pipe.

[209] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation,” California Public Utilities Commission, January 2014. Average of values for electric DHW (13 years) and gas DHW (11 years).
[210] Cost based on RS Means 2018 data
[211] Average cost of R-5 pipe wrap installation from the National Renewable Energy Laboratory’s National Residential Efficiency Measures Database, https://remdb.nrel.gov/.
[212] Ameren Missouri Energy Efficient Kits Impact and Process Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 78.

R_{Base} = Thermal resistance coefficient (hr-°F-ft^2)/Btu) of uninsulated pipe
= 1.0[213]

C_{EE} = Circumference (ft) of insulated pipe
= Diameter (in) * π/12
= Based on actual pipe diameter and insulation thickness; if unknown, assume 0.55" pipe diameter based on a weighted average of 80% 0.50-inch diameter pipe and 20% 0.75-inch diameter pipe and 0.5" insulation thickness – using both assumed values results in C_{EE} of (0.55 + (0.5 * 2)) * π / 12 = 0.4058
. For instance, for a pipe insulated with 3/4 in, R-4 wrap, assume 0.524 ft for a 0.46 in diameter pipe ((0.75 + 1/2 + 1/2) * π/12)

R_{EE} = Thermal resistance coefficient (hr-°F-ft^2)/Btu) of insulated pipe
= 1.0 + R value of insulation
= Actual

L = Length of pipe from water heating source covered by pipe wrap (ft)
= Actual

ΔT = Average temperature difference (°F) between supplied water and outside air
= Actual or if unknown, assume 58.9°F[214] for low income programs or 60°F[215] for other programs.

Hours = Hours per year
= 8,766

ηDHW_{Elec} = Recovery efficiency of electric hot water heater
= 0.98[216]

3,412 = Conversion factor from Btu to kWh

ISR = Actual, or if unknown, dependent on program delivery method as listed in table below

Program	ISR
School Kits	56%[217]
Multifamily	100%[218]
SFIE Kits	96%[219]
PAYS	100%[220]

Leakage = Percent homes outside service territory

Program	Leakage
School Kits	8.13%[221]
Other Programs	0%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, as calculated above.

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[213] "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets," Navigant, April 2009, https://www.oeb.ca/oeb/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf; 'Navigant_Appendix_C_substantiation_sheet_20090429.pdf', page C-77.
[214] Ameren Missouri Community Savers Evaluation PY2018, page 24.
[215] Assumes 125°F water leaving the hot water tank and average basement temperature of 65°F.
[216] Electric water heater recovery efficiency from AHRI database: http://www.ahridirectory.org/ahridirectory/pages/home.aspx.
[217] Ameren Missouri EE Kits Evaluation PY2019 Appendices Page 78.
[218] PY18 Energy Efficiency Kits School Evaluation Report, page 39.
[219] Ameren Missouri Community Savers Evaluation PY2018, page 24.
[220] Ameren Missouri PAYS Evaluation PY2022 Appendix, page 7.
[221] PY2018 Energy Efficiency Kits School Evaluation Report, page 39.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0000887318

NATURAL GAS SAVINGS

Custom calculation below for gas DHW systems, otherwise assume 1.1 therms per 6 linear feet of ¾ in, R-4 insulation or 1.5 therms per 6 linear feet of 1 in, R-6 insulation:

$$\Delta Therms = (1 - \%ElectricDHW) * ((C_{Base}/R_{Base} – C_{EE}/R\_{EE}) * L * \Delta T * Hours)/(\eta DHW_{Gas} * 100,000)$$

Where:

ηDHW_{Gas} = Recovery efficiency of gas hot water heater
= 0.78[222]

100,000 = Conversion factor from Btu to therms

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[222] 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%.

3.4 HVAC

3.4.1 Advanced Thermostat

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, or weather data and forecasts.[223] 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, so this measure treats these savings independently. This is a very active area of ongoing study 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.[224] That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations. Energy savings are applicable at the household level; installation of multiple advanced thermostats per home does not accrue additional savings.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure involves replacement of a manual-only or programmable thermostat with one that has the default-enabled capability or the automatic capability to 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 with regard to thermostat capability, usability, and sophistication. At a minimum, a qualifying thermostat must be capable of two-way communication[225] 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 thermostat type (manual or programmable), if known,[226] or an assumed mix of both 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, 44% programmable and 56% manual thermostats may be assumed.[227]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for advanced thermostats is assumed to be 11 years.[228]

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[223] For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of a home's thermal properties through user interaction. The thermostats optimize system operation based on equipment type and performance traits, such as using n weather forecasts, to demonstrate the type of automatic schedule change functionality that apply to this measure characterization.

[224] The ENERGY STAR® program discontinued its support for basic programmable thermostats effective 12/31/09 and is presently developing a new specification for "Residential Climate Controls."

[225] This measure recognizes that field data may be available, through the thermostat's two-way communication capability, to more accurately establish efficiency criteria and make 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.

[226] If the actual thermostat is programmable and is found to be used in override mode or otherwise is effectively being operated like a manual thermostat, then the baseline may be considered to be a manual thermostat.

[227] Value for blend of baseline thermostats comes from an Illinois potential study conducted by ComEd in 2013; Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study," Appendix 3: Detailed Mail Survey Results, April 2013, p. 34.

[228] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 204. Based on 2017 Residential Smart Thermostat Workpaper, prepared by SCE and Nest for SCE (Work Paper SCE17HC054, Revision #0, https://www.peakload.org/assets/SCE17HC054.0_Residential_Sma.pdf; 'SCE17HC054.0_Residential_Sma.pdf'). Estimate ability of smart systems to continue providing savings after disconnection and conduct statistical survival analysis which yields 9.2-13.8 year range.

DEEMED MEASURE COST
For DI and other programs where installation services are provided, the actual material, labor, and other costs should be referenced, and incremental cost of the advanced thermostat is equal to the actual total advanced thermostat material, labor, and other costs, minus the $50 baseline thermostat cost.

For retail or other program types where actual advanced thermostat costs are known, the incremental cost of the advanced thermostat is equal to the total cost of the advanced thermostat, minus the $50 baseline thermostat cost.[229]

If actual costs are unknown, then the incremental cost for the advanced thermostat is assumed to be $79.[230]

LOADSHAPE
Cooling RES
Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
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.

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

$\Delta kWh_{heating} = \%ElectricHeat * HeatingConsumption_{Electric} * HF * HeatingReduction * Eff\_ISR + (\Delta Therms * Fe * 29.3)$

$\Delta kWh_{cool} = \%AC * ((EFLH_{cool} * Capacity_{Cool} * 1/SEER2)/1000) * CoolingReduction * Eff\_ISR$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	33%[231]

$HeatingConsumption_{Electric}$ = If heating equipment characteristics are known, equals ((EFLHheat * CapacityHeat * 1/HSPF2)/1000); otherwise, estimate of annual household heating consumption for electrically heated homes.[232]

Weather Basis (Ameren Missouri Average)	Elec_Heating_ Consumption (kWh)[233]		
	Electric Resistance	Electric Heat Pump	Unknown Electric
SF or MF	14,202	8,355	11,456
MFc (comprehensive envelope)	4,832	2,843	3,898

[229] Actual costs include any one-time software integration, annual software maintenance, and/or individual device energy feature fees.
[230] 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. Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 204.
[231] Ameren Missouri Efficient Products Evaluation: PY2020, https://www.efis.psc.mo.gov/Document/Display/13830, page 40.
[232] Ameren Missouri Efficient Products Evaluation PY2018 workpapers. For Comprehensive Envelope (CompE) Measures, the ratio of MF effective full load hours (1496) to the Opinion Dynamic recommendation for Comprehensive Envelope full load hours (509) was used to scale heating consumption values.
[233] Ibid.

EFLHheat = Equivalent Full Load Heating Hours: [234]

Weather Basis (Ameren Missouri Average)	EFLHheat (Hours)
SF or MF	1496
MFc (comprehensive envelope)	510

CapacityHeat = Capacity of air cooling system (Btu/hr) (Note: One ton is equal to 12,000 Btu/hr.)
= Actual

HSPF2 = the cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh)
= Actual

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

Household Type	HF
Single-Family	100%
Multi-Family	65%[235]
If heating equipment characteristics are referenced to calculate $HeatingConsumption_{Electric}$	100%
Actual	Custom[236]

HeatingReduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat

Existing Thermostat Type	Heating_Reduction[237]
Manual	8.8%
Programmable	5.6%
Blended Average	6.67%

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication
= Actual, or if unknown, for Efficient Products, use 98.8%.[238], and for other programs, if using default savings, use 100%.[239]

ΔTherms = Therm savings if natural gas heating system
= See calculation in natural gas section below

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[240]

29.3 = kWh per therm

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

[234] Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.

[235] 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 multifamily homes with electric resistance, based on professional judgment that average household size, and heat loads of multifamily households are smaller than single family homes.

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

[237] These values represent adjusted baseline savings values for different existing thermostats, as presented in Navigant's IL TRM Workpaper on Impact Analysis from Preliminary Gas savings findings (page 28) https://www.ilsag.info/wp-content/uploads/SAG_files/Meeting_Materials/2015/December_2015_Meetings/Presentations/Smart_Tstat_Preliminary_Gas_Impact_Findings_2015-12-08_to_IL_SAG.pdf; 'Smart_Tstat_Preliminary_Gas_Impact_Findings_2015-12-08_to_IL_SAG.pdf'. The unknown assumption is calculated by multiplying the savings for manual and programmable thermostats by their respective share of baseline. Further evaluation and regular review of this key assumption is encouraged. Ameren Missouri Efficient Products Evaluation PY2017, https://www.efis.psc.mo.gov/Document/Display/14206, page 47.

[238] Ameren Missouri Efficient Products Evaluation PY2019, https://www.efis.psc.mo.gov/Document/Display/15877, page 140.

[239] 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.

[240] 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.

Thermostat control of air conditioning?	%AC
Yes	100%
No	0%
Unknown	Actual population data, or 91%[241]

$EFLH_{cool}$ = Equivalent full load hours of air conditioning:

Weather Basis (Ameren Missouri Average)	$EFLH_{cool}$ (Hours)
SF or MF	869[242]
MFc (comprehensive envelope)	632[243]

CapacityCool = Capacity of air cooling system (Btu/hr) (Note: One ton is equal to 12,000 Btu/hr.)
= Actual installed - If actual size unknown, assume 36,000 Btu/h
SEER2 = the cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh)
= Use actual SEER2 rating where it is possible to measure or reasonably estimate. If unknown assume 13.4 SEER2.[244]
1/1000 = kBtu per Btu
CoolingReduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat
= If programs are evaluated during program deployment then custom savings assumptions should be applied. Otherwise use:
= 8.0%[245]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh_{Cooling} * CF$

Where:

$\Delta kWh_{Cooling}$ = Electric energy savings for cooling, calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[246]

NATURAL GAS ENERGY SAVINGS

$\Delta Therms = \%FossilHeat * HeatingConsumption_{Gas} * HF * HeatingReduction * Eff_{ISR}$

Where:

%FossilHeat = Percentage of heating savings assumed to be natural gas

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	67%[247]

$HeatingConsumption_{Gas}$

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241 91% of homes have central cooling in Missouri (based on 2009 Residential Energy Consumption Survey, see 'RECS 2009 Air Conditioning_hc7.9.xls'), https://www.eia.gov/consumption/residential/data/2009/.
242 PY2019 evaluation report, https://www.efis.psc.mo.gov/Document/Display/15876, page 30
243 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.
244 Based on minimum federal standard.
245 This assumption is based upon the review of many evaluations from other regions in the United States. Cooling savings are more variable than heating due to significantly more variability in control methods and potential population and product capability.
246 Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors"for Residential Cooling.
247 Ameren Missouri Efficient Products Evaluation: PY2020, https://www.efis.psc.mo.gov/Document/Display/13830, page 41.

= Estimate of annual household heating consumption for gas heated single-family homes.[248]

Weather Basis (City based upon)	Gas_Heating_ Consumption (Therms)
St Louis, MO	682

Other variables as provided above.

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[248] Values in table are based on average household heating load (834 therms) for Chicago based on Illinois furnace metering study ((Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, https://www.icc.illinois.gov/docket/P2012-0528/documents/201939/files/355536.pdf ; '355536.pdf', Navigant, August 1 2013) and adjusted for Missouri climate region values using the relative climate- normal HDD data with a base temp ratio of 60°F. This load value is then divided by standard assumption of existing unit efficiency of 83.5% (estimate based on 29% of furnaces purchased in Missouri were condensing in 2000 (based on data from GAMA, provided to Department of Energy) (see 'Thermostat_ FLH and Heat Load Calcs.xls'). The resulting values are generally supported by data provided by Laclede Gas, which showed an average pre-furnace replacement consumption of 1009 therms for St Louis, and a post-replacement consumption of 909. Assuming a typical hot water consumption at 225 therms (using defaults from http://energy.gov/eere/femp/energy-cost-calculator-electric-and-gas-water-heaters-0#output), this indicates a heating load of 684-784 therms. Ameren Missouri Efficient Products Evaluation PY2017, https://www.efis.psc.mo.gov/Document/Display/14206, page 47.

3.4.2 Air Source Heat Pump Including Dual Fuel Heat Pumps

DESCRIPTION

An air source heat pump (ASHP) provides heating and/or cooling by moving heat between indoor and outdoor air. A cold climate air source heat pump (ccASHP) operates the same as a traditional ASHP, but is able to meet a home's full heating load at lower outdoor temperatures approaching 0°F. A dual fuel heat pump (DFHP) pairs an air source heat pump with a gas furnace such that the air source heat pump provides heating in mild weather, and as temperature drops the heat pump shuts off and the furnace provides heating. This measure may also apply to replacing a Central Air Conditioner with non-electric heating with an Air Source Heat Pump. In this case, only cooling savings (ER1, ER2, ROF) may be claimed using the ASHP cooling algorithm. This measure applies to central ducted systems and single zone split-systems with ductless indoor units that are capable of meeting a home's full cooling and heating demand.

This measure characterizes:

1. TOS, NC: The installation of a new residential sized (<= 65,000 Btu/hr) air source heat pump that is more efficient than required by federal standards. This could relate to the replacement of an existing ASHP at the end of its useful life or the installation of a new ASHP in a new home.
2. EREP: The early removal of functioning electric heating and cooling systems from service, prior to its natural end of life, and replacement with a new high efficiency ASHP unit. For the early replacement baseline to apply, program participants or installation contractors must provide documentation asserting that the existing units operated when turned on—whether or not they provided cooling—and the existing unit brand name and model number must be documented; or, if the nameplate is not readable, a photograph of the unit in context and the nameplate specifically must be provided. If the SEER and/or HSPF of the existing unit are known, the baseline SEER and/or baseline HSPF should be the actual values of the unit replaced. If unknown, use the assumptions provided in the variable list below ($SEER2_{exist}$ and $HSPF2_{exist}$). If the operational status of the existing unit is unknown, use TOS assumptions.

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

The heating capacity of the efficient heat pump should be within 90% to 120% of the capacity of the existing equipment, unless the trade ally can provide documentation confirming the existing system is oversized. It is recommended to collect the existing and new unit capacities to confirm that the heat pump has sufficient capacity to minimize use of backup electric resistance heating.

Using a dual fuel heat pump, which uses a gas furnace for heating at lower outside air temperatures, or a cold climate rated heat pump are two options to ensure minimal use of backup electric resistance heating.

DEFINITION OF BASELINE EQUIPMENT

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

The baseline for the TOS measure is the federal standard efficiency level; 14.3 SEER2 and 7.5 HSPF2, when replacing an existing air source heat pump; and 13.4 SEER2 and 3.41 HSPF when replacing a central air conditioner and electric resistance heating. Non-electric heating replaced with an air source heat pump can only claim cooling savings. Under the new federal standards, the M1 testing protocol was revised, resulting in new SEER and HSPF performance metrics, now called SEER2 and HSPF2. When quantifying energy savings, the SEER2 and HSPF2 metrics should be used for the existing, baseline, and new equipment. The following conversion formulas can be used to convert between efficiency metrics:

$$SEER2 = SEER * 0.96$$
$$HSPF2 = HSPF * 0.87$$

Non-electric heating replaced with an air source heat pump can only claim cooling savings.

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years.[249]
Remaining life of existing ASHP/CAC equipment is assumed to be 6 years[250] and 18 years for electric resistance.

DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the ASHP (including any necessary electrical or distribution upgrades required) should be used minus the assumed installation cost of the baseline equipment ($6,865 + $600 per ton for a new baseline ASHP[251], $2,011 for a new baseline 80% AFUE furnace or $4,053 for a new 84% AFUE boiler[252] and $3,338 for new baseline Central AC replacement[253]).

Early Replacement: The actual full installation cost of the ASHP (including any necessary electrical or distribution upgrades required) should be used. The assumed deferred cost (after the appropriate number of years described above) of replacing existing equipment with a new baseline unit is assumed to be $7,722 + $674 per ton for a new baseline ASHP, or $2,296 for a new baseline 80% AFUE furnace or $4,627 for a new 84% AFUE boiler and $3,670 for new baseline Central AC replacement.[254] This future cost should be discounted to present value using a 2.31% nominal societal discount rate, based on the ten year average (1/1/2014 – 12/31/2023) of the 10 year Treasury bond yield rates.[255]

If the install cost of the efficient ASHP is unknown, assume the following (note these costs are per ton of unit capacity);[256]

Efficiency (SEER2)	Full Efficient ASHP Cost (including labor)
15.2	$7,000 + $600/ ton
16.2	$7,286 + $600/ ton
17.1	$7,495 + $600/ ton
18.1	$7,720 + $600/ ton
19.0+	$7,946 + $600/ ton

When a non-electric heating system is replaced with an ASHP, and the program administrator is only claiming energy savings from cooling (i.e., no heating savings are claimed due to the fuel switch), the incremental costs should be adjusted to reflect the proportion of claimed savings.

The incremental cost of the ASHP shall be adjusted by applying a factor that represents the ratio of the claimed cooling savings to the total potential energy savings (inclusive of both cooling and unclaimed heating savings). This adjustment ensures that the incremental cost used in cost-effectiveness testing is proportional to the benefits being claimed, thus avoiding a mismatch between costs and benefits.

Calculation Method:

1. Determine Total Potential Savings: Calculate the sum of the potential energy savings from both cooling and heating (even if heating savings are not being claimed).
2. Determine Claimed Savings: Identify the portion of energy savings that is being claimed, typically the cooling savings only.
3. Apply the Adjustment Factor: The adjustment factor is calculated as the ratio of claimed savings to total potential savings. This factor is then applied to the full incremental cost of the ASHP.

Adjusted Incremental Cost = (Claimed Savings (kWh) / Total Potential Savings (kWh)) * Full Incremental Cost)

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[249] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, https://energizect.com/sites/default/files/documents/Measure%20Life%20Report%202007.pdf; 'Measure Life Report 2007.pdf', page 1-3.
[250] Assumed to be one third of effective useful life.
[251] 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.
[252] See 'Technical Standard Document_APPENDIX_E.pdf'.
[253] See 'CAC Costs 09.02.2024.xlsx'.
[254] All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.98%.
[255] 'Societal_Discount_Rate_Calculation_08082024.xlsx'.
[256] 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.

LOADSHAPE
Cooling RES
Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

TOS:

$\Delta kWh = [((EFLH_{cool} * Capacity_{cool} * (1/SEER2_{base} - 1/SEER2_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF2_{base} - 1/HSFP2_{ee})) / 1{,}000)] * ISR$

Cooling only for Central Air Conditioning and Non-Electric Heating Backup
$\Delta kWh = [((EFLH_{cool} * Capacity_{cool} * (1/SEER2_{base} - 1/SEER2_{ee})) / 1000) * ISR$

EREP:[257]

ΔkWh for remaining life of existing unit (1st 6 years for replacing an ASHP, 18 years for replacing electric resistance):
$= [((EFLH_{cool} * Capacity_{cool} * (1/SEER2_{exist} - 1/SEER2_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF2_{exist} - 1/HSFP2_{ee})) / 1{,}000)] * ISR$

Cooling only for Central Air Conditioning and Non-Electric Heating Backup
$\Delta kWh =[((EFLH_{cool} * Capacity_{cool} * (1/SEER2_{exist} - 1/SEER2_{ee})) / 1000) *ISR$

ΔkWh for remaining measure life (next 12 years if replacing an ASHP):
$=[((EFLH_{cool} * Capacity_{cool} * (1/SEER2_{base} - 1/SEER2_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF2_{base} - 1/HSFP2_{ee})) / 1{,}000)] * ISR$

Cooling only for Central Air Conditioning and Non-Electric Heating Backup
$\Delta kWh = [((EFLH_{cool} * Capacity_{cool} * (1/SEER2_{base} - 1/SEER2_{ee})) / 1000) * ISR$

Where:

$EFLH_{cool}$ = Equivalent full load hours of air conditioning:[258]

Weather Basis (Ameren Missouri Average)	$EFLH_{cool}$ (Hours)
SF or MF	869
MFc (comprehensive envelope)	632[259]

$Capacity_{cool}$ = Cooling Capacity of Air Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000Btu/hr)

$SEER2_{exist}$ = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

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[257] 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 either the new base to efficient savings or the (existing to efficient savings.
[258] PY2019 HVAC Evaluation, https://www.efis.psc.mo.gov/Document/Display/13830, page 4.
[259] Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.

= Use actual SEER2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate the efficiency value based on the age of the existing equipment (up to a maximum of 30 years) to account for degradation over time.[260] If age is unknown, use 12 years.

= SEER2 * $(1-0.01)^{Age}$

If rated efficiency is unknown, use defaults provided below, which are already adjusted to account for age-related degradation:

Existing Cooling System	$SEER2_{exist}$[261]
Air Source Heat Pump	6.91
Central AC	6.53
No central cooling[262]	Let ‘$1/SEER2_{exist}$’ = 0

$SEER2_{base}$ = Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)[263]
= 14.3 SEER2[264] when replacing an ASHP
= SEER2 13.4 when replacing a CAC

$SEER2_{ee}$ = Seasonal Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/kWh)
= Actual

$EFLH_{heat}$ = Equivalent full load hours of heating:[265]

Weather Basis (Ameren Missouri Average)	$EFLH_{heat}$ (Hours)
SF or MF	1496 for ASHP, 1119 for DFHP, and 1769[266] for ccAHSP
MFc (comprehensive envelope)	510[267] for ASHP and DFHP, and 603 for ccASHP

$Capacity_{heat}$ = Heating Capacity of Air Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000Btu/hr)

$HSPF2_{exist}$ = Heating Seasonal Performance Factor of existing heating system (kBtu/kWh)
= Use actual HSPF2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate the efficiency value based on the age of the existing equipment (up to a maximum of 30 years) to account for degradation over time.[268] If age is unknown, use 12 years.
= HSPF2 * $(1-0.01)^{Age}$
If rated efficiency is unknown, use defaults provided below, which should not be further adjusted to account for age-related degradation:

[260] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 112. Justification for degradation factors can be found on page 14 of ‘AIC HVAC Metering Study Memo FINAL 2_28_2018.docx’. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[261] ASHP existing efficiency assumes degradation and is sourced from the Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015. CAC assumed to follow the same trend in degradation as the ASHP: 9.12 SEER nameplate to 7.2 (6.91 SEER2) operations SEER represents degradation to 78.9% of nameplate. 78.9% of 8.6 SEER CAC nameplate gives an operational SEER of 6.8 (6.53 SEER2).

[262] 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.

[263] SEER to SEER2 conversion factor: SEER2 = SEER * 96%. Conversion factor for SEER to SEER2 is used when converting an existing system that is rated in SEER to SEER2. This is to meet the DOE M1 CFR Standard beginning January 1, 2023. The efficiency levels of the existing, baseline, and efficient case must be expressed in SEER2 terms before applying formulas.

[264] Based on minimum federal standard effective 1/1/2023: 10 CFR 430.32(c)(5)

[265] Ameren Missouri HVAC Evaluation PY2017, https://www.efis.psc.mo.gov/Document/Display/14208, page 37.

[266] Evaluation – Opinion Dynamics review PY2022. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) for St. Louis and technological differences between traditional and cold climate heat pumps, which are capable of meeting whole home heating requirements at lower temperatures than traditional heat pumps, resulting in increased effective full load operating hours.

[267] Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.

[268] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 112. Justification for degradation factors can be found on page 14 of ‘AIC HVAC Metering Study Memo FINAL 2_28_2018.docx’. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

Existing Heating System	$HSPF_{exist}$
Air Source Heat Pump	4.91[269]
Electric Resistance	3.41[270]

$HSPF2_{base}$ = Heating Seasonal Performance Factor of baseline Air Source Heat Pump (kBtu/kWh)[271]
= 7.5 HSPF2[272]

$HSFP2_{ee}$ = Heating Seasonal Performance Factor of efficient Air Source Heat Pump (kBtu/kWh)
= Actual

ISR = In-service rate. Actual, or if unknown, assume 100%[273]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{Cooling} * CF$$

Where:

$\Delta kWh_{Cooling}$ = Electric energy savings for cooling, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[269] Ibid., page 110.
[270] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
[271] HSPF to HSPF2 conversion factor: HSPF2 = HSPF * 87%. Conversion factor for HSPF to HSPF2 is used when converting an existing system that is rated in HSPF to HSPF2. This is to meet the DOE M1 CFR Standard beginning January 1, 2023. The efficiency levels of the existing, baseline, and efficient case must be expressed in HSPF2 terms before applying formulas.
[272] Based on minimum federal standard effective 1/1/2023: 10 CFR 430.32(c)(5)
[273] Ameren Missouri HVAC Evaluation: PY2020, https://www.efis.psc.mo.gov/Document/Display/13831, page 53.

3.4.3 Duct Sealing and Duct Repair

DESCRIPTION

This measure describes evaluating the savings associated with performing duct sealing to the distribution system of homes with central cooling and/or a ducted heating system. While sealing ducts in conditioned space can help with control and comfort, energy savings are largely limited to sealing ducts in unconditioned space where the heat loss is to outside the thermal envelope. Therefore, for this measure to be applicable at least 30% of ducts should be within unconditioned space (e.g., attic with floor insulation, vented crawlspace, unheated garages; basements should be considered conditioned space).

Three methodologies for estimating the savings associate from sealing the ducts are provided.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p. 44 of the Energy Conservatory Blower Door Manual; http://dev.energyconservatory.com/wp-content/uploads/2014/07/Blower-Door-model-3-and-4.pdf.
   It involves performing a whole house depressurization test and repeating the test with the ducts excluded.
2. **Duct Blaster Testing** - as described in RESNET Test 803.7:
   https://energyconservatory.com/wp-content/uploads/2014/09/RESNET-Standards-Chapter-8.pdf
   This involves using a blower door to pressurize the house to 25 Pascals and pressurizing the duct system using a duct blaster to reach equilibrium with the inside. The air required to reach equilibrium provides a duct leakage estimate.
3. **Deemed Savings per Linear Foot** – this method provides a deemed conservative estimate of savings and should only be used where performance testing described above is not possible.

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

The efficient condition is sealed duct work throughout the unconditioned space in the home.

DEFINITION OF BASELINE EQUIPMENT

The existing baseline condition is leaky duct work with at least 30% of the ducts within the unconditioned space in the home.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of this measure is 20 years.[274]

DEEMED MEASURE COST

The actual duct sealing measure cost should be used.

LOADSHAPE

HVAC RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Modified Blower Door Subtraction

a. Determine Duct Leakage rate before and after performing duct sealing:

$$\text{Duct Leakage } (CFM50_{DL}) = (CFM50_{Whole\ House} - CFM50_{EnvelopeOnly}) * SCF$$

Where:

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

[274] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, https://www.caetrm.com/media/reference-documents/HVAC_Ltg_measure_life_GDS_2007.pdf; 'HVAC_Ltg_measure_life_GDS_2007.pdf', page 1-3.

$CFM50_{Envelope\ Only}$ = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differentials 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 with respect to the building in the sealed duct system, with the building pressurized to 50 Pascals with respect to the outside. Use the following look up table provided by energy conservatory to determine the appropriate subtraction correction factor:

House to Duct Pressure	Subtraction Correction Factor
50	1.00
49	1.09
48	1.14
47	1.19
46	1.24
45	1.29
44	1.34
43	1.39
42	1.44
41	1.49
40	1.54
39	1.60
38	1.65
37	1.71
36	1.78
35	1.84
34	1.91
33	1.98
32	2.06
31	2.14

House to Duct Pressure	Subtraction Correction Factor
30	2.23
29	2.32
28	2.42
27	2.52
26	2.64
25	2.76
24	2.89
23	3.03
22	3.18
21	3.35
20	3.54
19	3.74
18	3.97
17	4.23
16	4.51
15	4.83
14	5.20
13	5.63
12	6.12
11	6.71

Calculate duct leakage reduction, convert to $CFM25_{DL,}$[275] and factor in Supply and Return Loss Factors:

Duct Leakage Reduction ($\Delta CFM25_{DL}$) = ($PreCFM50_{DL}$ – $PostCFM50_{DL}$) * 0.64 * (SLF + RLF)

Where:

0.64 = Converts $CFM50_{DL}$ to $CFM25_{DL}$[276]

SLF = Supply Loss Factor[277]
= % leaks sealed located in Supply ducts * 1
Default = 0.5[278]

[275] 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions.
[276] To convert CFM50 to CFM25, multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual).
[277] Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply 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 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 Blower Door Manual.
[278] Assumes 50% of leaks are in supply ducts.

RLF = Return Loss Factor[279]
= % leaks sealed located in Return ducts * 0.5
Default = 0.25[280]

Calculate electric savings

$\Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$

If the home has central cooling, the electric energy saved in annual cooling due to the duct sealing and repair is:

$\Delta kWh_{Cooling} = (\Delta CFM25_{DL}/((Capacity_{Cool}/12{,}000 * 400)) * EFLHcool * Capacity_{Cool})/(1{,}000 * SEER2)$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM2 as calculated above
CapacityCool = Capacity of Air Cooling system (Btu/hr)
= Actual
12,000 = Converts Btu/H capacity to tons
400 = Conversion of Capacity to CFM (400CFM / ton) [281]
EFLHcool = Equivalent Full Load Cooling Hours:[282]

Weather Basis (Ameren Missouri Average)	EFLHcool (Hours)
SF or MF	869
MFc (comprehensive envelope)	632[283]

1,000 = Converts Btu to kBtu
SEER2 = Seasonal Energy Efficiency Ratio of Air Conditioning equipment (kBtu/kWh)
= Actual - If not available, following: [284]

Age of Equipment	ηCool Estimate
Before 2006	9.5
2006 - 2014	12.4
Central AC After 1/1/2015	12.4
Heat Pump After 1/1/2015	13.3

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$\Delta kWhHeating_{Electric} = (\Delta CFM25_{DL}/((Capacity_{Heat}/12{,}000 * 400)) * EFLH_{heat} * Capacity_{Heat})/(COP * 3{,}412)$

Where:

CapacityHeat = Heating output capacity (Btu/hr) of electric heat
= Actual
EFLHheat = Equivalent Full Load Heating Hours: [285]

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[279] 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 Blower Door Manual.
[280] Assumes 50% of leaks are in return ducts.
[281] This conversion is an industry rule of thumb. E.g., see https://www.brinco.com/2016/02/04/is-there-a-rule-of-thumb-that-i-can-use-that-would-tell-me-how-many-cfms-an-ac-would-need-per-ton-of-cooling-capacity/
[282] https://www.efis.psc.mo.gov/Document/Display/15876, page 30
[283] Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.
[284] 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. Note all ratings have been converted to SEER2 equivalents – since the new rating better reflects the actual efficiency of the units.
[285] Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.

Weather Basis (Ameren Missouri Average)	EFLHheat (Hours)
SF or MF	1496
MFc (comprehensive envelope)	510

COP = Efficiency in COP of Heating equipment
= Actual - If not available, use:

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[286]	N/A	N/A	1.28

3412 = Converts Btu to kWh

If the home is heated with natural gas, the electric energy saved in annual heating due to the added insulation is:

$\Delta kWhHeating_{Gas}$ = (ΔTherms * Fe * 29.3)

Where:

ΔTherms = Therm savings as calculated in Natural Gas Savings

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[287]

29.3 = kWh per therm

Methodology 2: Duct Blaster Testing

ΔkWh = ΔkWhCooling + ΔkWhHeating

$\Delta kWh_{Cooling}$ = ((Pre_CFM25 – Post_CFM25)/(CapacityCool/12,000 * 400) * EFLHcool * CapacityCool)/(1,000 * SEER2)

$\Delta kWhHeating_{Electric}$ = ((Pre_CFM25 – Post_CFM25)/(CapacityHeat/12,000 * 400) * EFLHheat * CapacityHeat)/(COP * 3,412)

$\Delta kWhHeating_{Gas}$ = ΔTherms * Fe * 29.3

Where:

Pre_CFM25 = Duct leakage in CFM25 as measured by duct blaster test before sealing

Post_CFM25 = Duct leakage in CFM25 as measured by duct blaster test after sealing

All other variables as provided above

Methodology 3: Deemed Savings[288]

ΔkWh = $\Delta kWh_{Cooling}$ + $\Delta kWh_{HeatingElectric}$ + $\Delta kWh_{HeatingGas}$

$\Delta kWh_{cooling}$ = CoolSavingsPerUnit * $Duct_{Length}$

$\Delta kWhHeating_{Electric}$ = HeatSavingsPerUnit * $Duct_{Length}$

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[286] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.

[287] 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.

[288] Savings per unit are based upon analysis performed by Cadmus for the 2011 Iowa Joint Assessment of Potential. It was based on 10% savings in system efficiency. This would represent savings from homes with significant duct work outside of the thermal envelope. With no performance testing or verification, a deemed savings value should be very conservative and therefore the values provided in this section represent half of the savings – or 5% improvement. These values are provided as a conservative deemed estimate for Missouri, while encouraging the use of performance testing and verification for determination of more accurate savings estimates.

$\Delta kWhHeating_{Ga}$ = ΔTherms * Fe * 29.3

Where:

CoolSavingsPerUnit = Annual cooling savings per linear foot of duct[289]

Building Type	HVAC System	CoolSavingsPerUnit (kWh/ft)
Multifamily	Cool Central	0.70
Single-family	Cool Central	0.81
Manufactured	Cool Central	0.95
Multifamily	Heat Pump—Cooling	0.70
Single-family	Heat Pump—Cooling	0.81
Manufactured	Heat Pump—Cooling	0.95

$Duct_{Length}$ = Linear foot of duct
= Actual

HeatSavingsPerUnit = Annual heating savings per linear foot of duct[290]

Building Type	HVAC System	HeatSavingsPerUnit (kWh/ft)
Manufactured	Heat Pump—Heating	5.06
Multifamily	Heat Pump - Heating	3.41
Single-family	Heat Pump— Heating	4.11

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh * CF

Where:

ΔkWh = Electric energy savings, as calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0004660805[291]

NATURAL GAS SAVINGS

For homes with Natural Gas Heating:

Methodology 1: Modified Blower Door Subtraction

ΔTherm = (ΔCFM25DL/((CapacityHeat * 0.0136)) * EFLHheat * CapacityHeat * ηEquipment / ηSystem)/100,000

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25
= As calculated in Methodology 1 under electric savings
CapacityHeat = Heating input capacity (Btu/hr)
= Actual
0.0125 = Conversion of Capacity to CFM (0.0125CFM / Btu/hr)[292]
ηEquipment = Heating Equipment Efficiency

[289] MO TRM, page 97, https://dnr.mo.gov/document-search/missouri-technical-reference-manual-2017-volume-3-residential-measures
[290] MO TRM, page 97, https://dnr.mo.gov/document-search/missouri-technical-reference-manual-2017-volume-3-residential-measures
[291] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for Residential Cooling."
[292] 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 https://www.contractingbusiness.com/archive/article/20861289/calculating-heating-system-airflow). Data provided by GAMA during the federal rulemaking process for furnace efficiency standards, suggested that in 2000, 29% of furnaces purchased in Missouri 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 125 per 10,000Btu or 0.0125/Btu.

= Actual[293] - If not available, use 83.5%[294]
ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[295]
= Actual - If not available use 71.0%[296]
100,000 = Converts Btu to therms

Methodology 2: Duct Blaster Testing

ΔTherms = ((Pre_CFM25 – Post_CFM25)/(ΔCFM25DL/CapacityHeat) * 0.0136 * EFLHgasheat * Equipment / ηSystem)/100,000

Where:

All variables as provided above

Methodology 3: Deemed Savings[297]

ΔTherms = HeatSavingsPerUnit*$Duct_{Length}$

Where:

HeatSavingsPerUnit = Annual heating savings per linear foot of duct[298]

Building Type	HVAC System	HeatSavingsPerUnit (Therms/ft)
Multifamily	Heat Central Furnace	0.19
Single-family	Heat Central Furnace	0.21
Manufactured	Heat Central Furnace	0.26

$Duct_{Length}$ = Linear foot of duct
= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[293] The actual Heating Equipment Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. If there is more than one heating system, 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.
[294] In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 16 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: (0.29*0.92) + (0.71*0.8) = 0.835.
[295] 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 - (https://www.bpi.org/__cms/docs/Guidance%20on%20Estimating%20Distribution%20Efficiency.pdf; 'Guidance on Estimating Distribution Efficiency.pdf') - or by performing duct blaster testing.
[296] Estimated as follows: 0.835 * (1-0.15) = 0.710.
[297] Savings per unit are based upon analysis performed by Cadmus for the 2011 Joint Assessment of Potential. It was based on 10% savings in system efficiency. This would represent savings from homes with significant duct work outside of the thermal envelope. With no performance testing or verification, a deemed savings value should be very conservative and therefore the values provided in this section represent half of the savings – or 5% improvement. These values are provided as a conservative deemed estimate for Missouri, while encouraging the use of performance testing and verification for determination of more accurate savings estimates.
[298] Iowa TRM v8.0, page 204, https://wcc.efs.iowa.gov/cs/idcplg?IdcService=GET_FILE&allowInterrupt=1&RevisionSelectionMethod=latest&dDocName=2129208&noSaveAs=1

3.4.4 Mini/Multi-Split Air Source Heat Pump and Air Conditioners

DESCRIPTION

This measure is designed to calculate electric savings from retrofitting existing electric HVAC systems with ductless and/or ducted mini/multi-split heat pumps (MMSHPs) or mini/multi-split air conditioners. MMSHPs save energy in heating mode because they provide heat more efficiently than electric resistance heat and central ASHP systems. Additionally, MMSHPs use less fan energy to move heat and don't incur heat loss through a lengthy duct distribution system while operating at very low static pressure. Often MMSHPs are installed in addition to (do not replace) existing heating or cooling equipment because the existing heating or cooling equipment is inadequate to efficiently heat or cool the space. Both ductless and ducted indoor units can be installed as a mixed mini/multi-split heat pump or air conditioner under this measure. Duct runs for a ducted mini/multi-split indoor unit should be installed within the conditioned envelope, be well-sealed and insulated ducts, and maintain low static pressure per manufacturer specifications for the installation configuration to maximize energy savings.

For cooling, the proposed savings calculations are aligned with those of typical replacement systems. MMSHPs save energy in cooling mode because they provide cooling capacity more efficiently than other types of unitary cooling equipment. A MMSHPs installed in a home with an existing central ASHP or CAC system will save energy by offsetting some of the cooling energy of the ASHP or CAC. In order for this measure to apply, the control strategy for the heat pump or air conditioner is assumed to be chosen to maximize savings per installer recommendation.[299]

This measure was developed to be applicable to the following program type: NC, ROF, and ER.

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 and/or ducted mini/multi-split heat pump or air conditioning system that exceeds the program minimum efficiency requirements.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, baseline equipment must include a permanent electric resistance heating source or a ducted air-source heat pump or ducted air conditioner. For residences with central air conditioner/non-electric heating, cooling savings will only apply. For multifamily buildings, each residence must have existing individual heating equipment. Multifamily residences with central heating do not qualify for this characterization. Existing cooling equipment is assumed to be standard efficiency. Note that in order to claim cooling savings, there must be an existing air conditioning system (e.g. central air conditioning, Window ACs, or air source heat pump).

New federal standards affecting heat pumps became effective January 1, 2023. Under the new standards, the baseline for a ROF measure is the federal standard efficiency; 14.3 SEER2 and 7.5 HSPF2 when replacing a ducted air-source heat pump; 13.4 SEER2 and 3.41 HSPF2 when replacing a central air conditioner and electric resistance heating; 13.4 SEER2 when replacing central air conditioner with non-electric heating or no heating.

Under the new federal standards, the M1 testing protocol was revised, resulting in new SEER and HSPF performance metrics, now called SEER2 and HSPF2. When quantifying energy savings, the SEER2 and HSPF2 metrics should be used for the existing, baseline, and new equipment. The following conversion formulas can be used to convert between efficiency metrics:

$$SEER2 = SEER * 0.96$$
$$HSPF2 = HSPF * 0.87$$

For the early replacement baseline to apply, program participants or installation contractors must provide documentation asserting that the existing units operated when turned on—whether or not they provided cooling—and the existing unit brand name and model number must be documented; or, if the nameplate is not readable, a photograph of the unit in context and the nameplate specifically must be provided. 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.

[299] 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 control 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 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years.[300]

Remaining life of existing ASHP/CAC equipment is assumed to be 6 years301 and 18 years for electric resistance.

DEEMED MEASURE COST

Default full cost of the MMSHP is provided below. Note, for smaller units a minimum cost of $2,000 should be applied:[302]

Unit HSPF2	Full Install Cost ($/ton)[303]
8.1-8.9	$1,443
9-9.8	$1,605
9.9-11.6	$1,715
11.7+	$2,041

New Construction and Time of Sale: If the unit is not displacing electric resistance heating or facilitating fuel switching, apply the incremental cost of the MMSHP compared to a baseline minimum efficiency MMSHP provided in the table below:[304]

Efficiency (HSPF2)	Incremental Cost ($/ton) over an HSPF2 7.5 MMSHP
8.1-8.9	$62
9-9.8	$224
9.9-11.6	$334
11.7+	$660

Otherwise, the incremental cost should be calculated as the greater of:

- Actual installed cost of the MMSHP should be used (defaults are provided above), minus the assumed installation cost of the baseline equipment ($2,011 for a new baseline 80% AFUE furnace,[305] and $3,338 for new baseline Central AC replacement [306]). If replacing electric resistance heat, there is no deferred cost for replacing the electric resistance heating unit.
- Applicable incremental cost relative to MMSHP identified in the table above.

Early Replacement/retrofit (replacing existing equipment): If available, the actual full installation cost of the MMSHP should be used; if unavailable, the default full cost specified above should be used. The assumed deferred cost of replacing existing equipment with a new baseline unit is assumed to be $1,518[307] per ton for a new baseline MMSHP, or $2,296 for a new baseline 80% AFUE furnace and $3,670 for new baseline Central AC replacement.[308] If replacing electric resistance heat, there is no deferred cost for replacing the electric resistance heating unit. This future cost should be discounted to present value using a 2.31% nominal societal discount rate, based on the ten year average (1/1/2014 – 12/31/2023) of the 10 year Treasury bond yield rates. [309]

If the deferred replacement cost exceeds the full installation cost of the MMSHP, the incremental cost shall be set to zero.

When a non-electric heating system is replaced with an MMSHP, and the program administrator is only claiming energy savings from cooling (i.e., no heating savings are claimed due to the fuel switch), the incremental costs should be adjusted to reflect the proportion of claimed savings.

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[300] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007, https://www.caetrm.com/media/reference-documents/HVAC_Ltg_measure_life_GDS_2007.pdf; 'HVAC_Ltg_measure_life_GDS_2007.pdf', page 1-3.

[301] Assumed to be one third of effective useful life.

[302] 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.

[303] 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.

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

[305] See 'Technical Standard Document_APPENDIX_E.pdf'.

[306] See 'CAC Costs 09.02.2024.xlsx'.

[307] Based on implicit standard efficiency cost of $1,381 per ton (8.1-8.9 HSPF2 per ton full cost minus incremental cost), account for inflation rate of 1.91%.

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

[309] 'Societal_Discount_Rate_Calculation_08082024.xlsx'.

The incremental cost of the MMSHP shall be adjusted by applying a factor that represents the ratio of the claimed cooling savings to the total potential energy savings (inclusive of both cooling and unclaimed heating savings). This adjustment ensures that the incremental cost used in cost-effectiveness testing is proportional to the benefits being claimed, thus avoiding a mismatch between costs and benefits.

Calculation Method:

1. Determine Total Potential Savings: Calculate the sum of the potential energy savings from both cooling and heating (even if heating savings are not being claimed).
2. Determine Claimed Savings: Identify the portion of energy savings that is being claimed, typically the cooling savings only.
3. Apply the Adjustment Factor: The adjustment factor is calculated as the ratio of claimed savings to total potential savings. This factor is then applied to the full incremental cost of the MMSHP.

Adjusted Incremental Cost = (Claimed Savings (kWh) / Total Potential Savings (kWh)) * Full Incremental Cost)

LOADSHAPE
Cooling RES
Heating RES

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
Electric savings

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

Heating savings:

TOS:

$\Delta kWh_{heating} = ((Capacity_{heat} * EFLH_{heat} * (1/HSPF2_{base} - 1/HSPF2_{ee})) / 1000) * HF * ISR$

EREP:

$\Delta kWh_{heating} = ((Capacity_{heat} * EFLH_{heat} * (1/HSPF2_{exist} - 1/HSPF2_{ee})) / 1000) * HF * ISR$

Where:

$Capacity_{heat}$ = Heating capacity of the ductless heat pump unit in Btu/hr
= Actual

$EFLH_{heat}$ = Equivalent Full Load Hours for heating. See table below:

Weather Basis (Ameren Missouri Average)	$EFLH_{heat}$[310]
SF or MF	1,034
MFc (comprehensive envelope)	393

[310] Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.

$HSPF2_{exist}$ = Use actual HSPF2 rating where it is possible to measure or reasonably estimate. HSPF2 rating of existing equipment. If rated efficiency is unknown, use defaults provided below

Existing Equipment Type	$HSPF2_{exist}$[311]
Electric resistance heating	3.412
Air Source Heat Pump	6.58

$HSPF2_{base}$ = HSPF2 rating of baseline equipment (kBtu/kWh)
= 7.5 HSPF2[312] when replacing an ASHP
= 3.412 when replacing electric resistance heating

$HSPF2_{ee}$ = HSPF rating of new equipment (kBtu/kWh)
= Actual installed

ISR = In-service rate. Actual, or if unknown, assume 100%[313]

Cooling savings calculated only in presence of non-electric heating or MMAC (Mini/Multi-Split AC):

TOS:

$\Delta kWh_{cooling}$ = $((Capacity_{cool} * EFLH_{cool} * (1/SEER2_{base} - 1/SEER2_{ee})) / 1000) * HF * ISR$

EREP:

$\Delta kWh_{cooling}$ = $((Capacity_{cool} * EFLH_{cool} * (1/SEER2_{exist} - 1/SEER2_{ee})) / 1000) * HF * ISR$

Where:

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr.[314]
= Actual installed

$SEER2_{exist}$ = SEER rating of existing equipment (kBtu/kWh)

= Use actual SEER rating where possible to measure or reasonably estimate. If using rated efficiencies, derate the efficiency value based on the age of the existing equipment (up to a maximum of 30 years) to account for degradation over time.[315] If age is unknown, use 12 years.
= $SEER2 * (1-0.01)^{Age}$

If unknown, see table below

Existing Cooling System	$SEER2_{exist}$[316]
Air Source Heat Pump	6.91
Central AC	6.53
Room AC	6.3[317]
No existing cooling[318]	Let '1/SEER_exist' = 0

[311] Ameren Missouri Heating and Cooling Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/15871, page 36.
[312] Based on minimum federal standard effective 1/1/2023: 10 CFR 430.32(c)(5)
[313] Ameren Missouri HVAC Evaluation: PY2020, https://www.efis.psc.mo.gov/Document/Display/13831, page 53.
[314] 1 Ton = 12 kBtu/hr.
[315] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 112. Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018.docx'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).
[316] ASHP existing efficiency assumes degradation and is sourced from the Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015. CAC assumed to follow the same trend in degradation as the ASHP: 9.12 SEER nameplate to 7.2 (6.91 SEER2) operations SEER represents degradation to 78.9% of nameplate. 78.9% of 8.6 SEER CAC nameplate gives an operational SEER of 6.8 (6.53 SEER2). 78.9% of 8.0 SEER RAC nameplate gives an operational SEER of 6.3.
[317] Estimated by converting the EER assumption using the conversion equation; $EER\_base = (-0.02 * SEER\_base^2) + (1.12 * SEER)$. From Wassmer, M. (2003), "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations," (Masters thesis) University of Colorado at Boulder. Adjusted to account for degradation per above footnote.
[318] If there is no existing cooling in place but the incentive encourages installation of a new DMSHP with cooling, the added cooling load should be subtracted from any heating benefit.

$SEER2_{base}$ = Seasonal Energy Efficiency Ratio of baseline equipment (kBtu/kWh)[319]
= 14.3 SEER2[320] when replacing an ASHP
= 13.4 SEER2 when replacing a CAC
$SEER2_{ee}$ = SEER rating of new equipment (kBtu/kWh)
= Actual installed[321]
$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. See table below

Weather Basis (Ameren Missouri Average)	$EFLH_{cool}$
SF or MF	635
MFc (comprehensive envelope)	417

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh_{Cooling} * CF$

Where:

$\Delta kWh_{Cooling}$ = Electric energy savings for cooling, calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[319] SEER to SEER2 conversion factor: SEER2 = SEER * 96%. Conversion factor for SEER to SEER2 is used when converting an existing system that is rated in SEER to SEER2. This is to meet the DOE M1 CFR Standard beginning January 1, 2023. The efficiency levels of the existing, baseline, and efficient case must be expressed in SEER2 terms before applying formulas.
[320] Based on minimum federal standard effective 1/1/2023: 10 CFR 430.32(c)(5)
[321] 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.

3.4.5 Standard Programmable Thermostat

DESCRIPTION
This measure characterizes the household energy savings from the installation of a new standard programmable thermostat for reduced heating and cooling energy consumption through temperature set-back during unoccupied or reduced demand times.

Energy savings are applicable at the household level; installation of multiple programmable thermostats per home does not accrue additional savings.

If the home has a heat pump, a programmable thermostat specifically designed for heat pumps should be used to minimize the use of backup electric resistance heat systems.

This measure was developed to be applicable to the following program types: DI. This measure is only applicable for low income programs. Savings will not be claimed for this measure for programs other than low income programs.

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.

DEFINITION OF BASELINE EQUIPMENT
For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature set point.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected equipment life of a programmable thermostat is assumed to be 10 years.[322]

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 is assumed to be $70.[323]

LOADSHAPE
Cooling RES
Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
For central air conditioners and air source heat pumps:

$\Delta kWh_{cool} = EFLH_{cool} * Capacity_{Cooling} * (1/SEER2) * SBdegrees * SF * EF / 1,000 * ISR$

For air source heat pumps there are additional heating savings:

$\Delta kWh_{heat} = EFLH_{heat} * Capacity_{Heating} * (1/HSPF2) * SBdegrees * SF * EF / 1,000 * ISR$

Where:

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[322] Table 1, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, https://energizect.com/sites/default/files/documents/Measure%20Life%20Report%202007.pdf; 'Measure Life Report 2007.pdf', page 1-3.
. Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer-term impacts should be assessed.
[323] 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 $30. Labor is assumed to be one hour at $40 per hour.

$EFLH_{cool}$ = Equivalent full load hours of air conditioning[324]:

Weather Basis (Ameren Missouri Average)	$EFLH_{cool}$ (Hours)
SF or MF	869
MFc (comprehensive envelope)	632

$Capacity_{Cooling}$ = Cooling capacity of system in BTU/hr (1 ton = 12,000 BTU/hr)
= Use Actuals based upon units served

SEER2 = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)
= Actual. If unknown, use defaults provided below:

Cooling System	SEER
Air Source Heat Pump	10[325]
Central AC	10[326]

HSPF2 = Heating Season Performance Factor of heating system (kBtu/kWh)
= Actual. If unknown, use defaults provided below:

Existing Heating System	HSPF2
Air Source Heat Pump	7.00[327]
Electric Resistance	3.41[328]

$EFLH_{heat}$ = Equivalent full load hours of heating:[329]

Weather Basis (Ameren Missouri Average)	$EFLH_{heat}$ (Hours)
SF or MF	1496
MFc (comprehensive envelope)	510

$Capacity_{Heating}$ = Heating capacity of system in BTU/hr (1 ton = 12,000 BTU/hr)
= Use Actuals based upon units served

SBdegrees = weighted sum of setback degrees to comfort temperature
= SBdegrees Heating = 1.8[330]
= SBdegrees Cooling = 1.91[331]

SF = Savings factors from ENERGY STAR® calculator
= 3% / degree heat, 6% / degree cool

EF = Efficiency ratio from Cadmus metering study
= 13% heat[332]
= 100% cool[333]

ISR = In-service rate
= Actual, or if unknown, assume 100%.

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324 Ameren Missouri Program Year 2019 Annual EM&V Report Volume 2: Residential Portfolio Appendices, https://www.efis.psc.mo.gov/Document/Display/15876, page 30.
325 Ameren Missouri Community Saver Program Evaluation PY2018 https://www.efis.psc.mo.gov/Document/Display/36053, page 26.
326 Ameren Missouri Community Saver Program Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/36053, page 26.
327 IL-TRM (Based on minimum federal standards between 1992 and 2006) – Ameren Missouri Community Saver Program Evaluation PY2018.
328 Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
329 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations, https://www.efis.psc.mo.gov/Document/Display/15876, page 76.
330 Ameren Missouri Community Saver Program Evaluation PY2018 Site Visit Thermostat SB Data.
331 Ameren Missouri Community Saver Program Evaluation PY2018Site Visit Thermostat SB Data.
332 Ameren Missouri Community Saver Program Evaluation PY2014 Cadmus metering study, https://www.efis.psc.mo.gov/Document/Display/15857, (PY2014 pg. 31).
333 Ameren Missouri Community Saver Program Evaluation PY2017, https://www.efis.psc.mo.gov/Document/Display/28281.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh_{Cooling} * CF$

Where:

$\Delta kWh_{Cooling}$ = Electric energy savings for cooling, calculated above
CF = 0.0009474181

NATURAL GAS ENERGY SAVINGS

$\Delta Therms = \%FossilHeat * HeatingConusmption_{Gas} * HF * Heating_{Reduction} * Eff_{ISR} * PF$

Where:

%FossilHeat = Percentage of heating savings assumed to be natural gas

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	65%[334]

$HeatingConsumption_{Gas}$ = Estimate of annual household heating consumption for gas heated single-family homes.[335]

Weather Basis (City based upon)	Gas_Heating_ Consumption (Therms)
St Louis, MO	680

Other variables as provided above.

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

334 Average (default) value of 65% gas space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

335 Values in table are based on average household heating load (834 therms) for Chicago based on Illinois furnace metering study (Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, https://www.icc.illinois.gov/docket/P2012-0528/documents/201939/files/355536.pdf ; '355536.pdf', Navigant, August 1 2013) and adjusted for Missouri weather basis values using the relative climate normals HDD data with a base temp ratio of 60°F. This load value is then divided by standard assumption of existing unit efficiency of 83.5% (estimate based on 29% of furnaces purchased in Missouri were condensing in 2000 (based on data from GAMA, provided to Department of Energy) (see 'Thermostat_ FLH and Heat Load Calcs.xls'). The resulting values are generally supported by data provided by Laclede Gas, which showed an average pre-furnace replacement consumption of 1009 therms for St Louis, and a post-replacement consumption of 909. Assuming a typical hot water consumption at 225 therms (using defaults from http://energy.gov/eere/femp/energy-cost-calculator-electric-and-gas-water-heaters-0#output), this indicates a heating load of 684-784 therms.

3.4.6 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. Tune-up activities include a general tune-up, refrigerant charge, indoor coil cleaning, and outdoor coil cleaning. These tune-up actions may be performed individually or as a packaged service with more than one tune-up activity.

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

A tuned and commissioned residential central air conditioning unit or air source heat pump.

DEFINITION OF BASELINE EQUIPMENT

An existing residential central air conditioning unit or air source heat pump that has required tuning to restore optimal performance.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 2 years.[336]

DEEMED MEASURE COST

As a RF measure, actual costs should be used. If unavailable, the measure cost should be assumed to be $175.[337] The table below identifies more specific costs for varying services.

<table>
<tr><th>Tune- up Service for HP or AC</th><th colspan="2">Incremental Cost ($)</th></tr>
<tr><td>General Tune-Up (no charge or coil clean)</td><td colspan="2">$70.00</td></tr>
<tr><td>Tune-up / refrigerant charge</td><td>$81.00</td><td rowspan="3">$175.00</td></tr>
<tr><td>Tune-up / Indoor Coil (Evaporator) Cleaning</td><td>$63.00</td></tr>
<tr><td>Tune-up / Outdoor Coil (Condenser) Cleaning</td><td>$31.00</td></tr>
<tr><td>Tune-Up / Packaged Service</td><td colspan="2">$185[338]</td></tr>
</table>

LOADSHAPE

Cooling RES
Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh_{Central\ AC}$ = $((EFLH_{cool} * Capacity_{cool} * (1/SEER_{test\text{-}in} - 1/SEER_{test\text{-}out})) / 1{,}000)$

ΔkWh_{ASHP} = $((EFLH_{cool} * Capacity_{cool} * (1/SEER_{test\text{-}in} - 1/SEER_{test\text{-}out})) / 1{,}000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{test\text{-}in} - 1/HSFP_{test\text{-}out})) / 1{,}000)$

Where:

$EFLH_{cool}$ = Equivalent full load hours of air conditioning
= dependent on location:[339]

$Capacity_{cool}$ = Cooling Capacity of Air Source Heat Pump (Btu/hr)

[336] Sourced from DEER Database Technology and Measure Cost Data.
[337] Based on personal communication with HVAC efficiency program consultant Buck Taylor of Roltay Inc., 6/21/10, who estimated the cost of tune up at $125 to $225, depending on the market and the implementation details.
[338] Estimated average packaged tune-up cost based on implementer data from 2015-2016.
[339] PY2019 Residential Evaluation Report Appendices, https://www.efis.psc.mo.gov/Document/Display/15876, page 35.

= Actual

$SEER_{test\text{-}in}$ = Seasonal Energy Efficiency Ratio of existing cooling system before tuning (kBtu/kWh)
= In most instances, test-in EER will be determined and noted prior to tuning. SEER rating can be estimated by using the following relationship:[340] $EER = (-0.02 * SEER^2) + (1.12 * SEER)$
When unknown,[341] assume SEER = 11.9

$SEER_{test\text{-}out}$ = Seasonal Energy Efficiency Ratio of existing cooling system after tuning (kBtu/kWh)
= In most instances, test-out EER will be determined and noted after tuning. SEER rating can be estimated by using the following relationship:[342] $EER = (-0.02 * SEER^2) + (1.12 * SEER)$; if unknown, reference applicable assumed value in table below.

$EFLH_{heat}$ = Equivalent full load hours of heating:

$Capacity_{heat}$ = Heating Capacity of Air Source Heat Pump (Btu/hr)
= Actual

$HSPF_{test\text{-}in}$ = Heating Seasonal Performance Factor of existing ASHP before tuning (kBtu/kWh)
= Actual, or if unknown, assume HSPF = 6.3.[343]

$HSPF_{test\text{-}out}$ = Heating System Performance Factor of existing ASHP after tuning (kBtu/kWh)
= Actual, or if unknown, reference applicable assumed value in table below.

Weather Basis (Ameren Missouri Average)	$EFLH_{cool}$ (Hours)	$EFLH_{heat}$ (Hours)
SF or MF	869[344]	1496[345]
MFc (comprehensive envelope)	632[346]	510[347]

When SEER test-in and test-out values are unknown, tune-ups are assumed to improve efficiency as follows:

Measure	% Improvement	$SEER_{test\text{-}out}$ (based on default 11.9 test-in value)
Refrigerant charge adjustment	28.4%[348]	15.3
Condenser Cleaning Only	7.9%[349]	12.8
Indoor coil cleaning	3.8%[350]	12.4
General tune-up	5.6%[351]	12.6
Packaged Service	13.6%[352]	13.8

When HSPF test-out values are unknown, use the following default test-out values based on the tune-up service(s) performed:

340 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.
341 Using aforementioned relationship and test-in efficiency of 10.5 EER, as listed in "Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015" https://www.efis.psc.mo.gov/Document/Display/13806, page 43.
342 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.
343 Based on evaluation results outlined in "Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015.", https://www.efis.psc.mo.gov/Document/Display/13806
344. PY2019 Evaluation Report Appendices, https://www.efis.psc.mo.gov/Document/Display/15876, page 76.
345 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations, https://www.efis.psc.mo.gov/Document/Display/15876, page 76.
346 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations
347 Ibid.
348 Ameren Missouri PY2015 Evaluation, page 42, https://www.efis.psc.mo.gov/Document/Display/13806.
349 Ibid.
350 Ibid.
351 MO TRM, page 114, https://dnr.mo.gov/document-search/missouri-technical-reference-manual-2017-volume-3-residential-measures.
352 Average percentage improvement across 74 packaged service tune-up measures in the Ameren Missouri PY2019 Low Income Multifamily program.

Measure	$HSPF_{test-out}$ (based on default 6.3 test-in value)
Refrigerant charge adjustment	6.72
Condenser Cleaning Only	6.42
Indoor coil cleaning	6.36
General tune-up	6.38
Packaged Service	7.29[353]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{Cooling} * CF$$

Where:

$\Delta kWh_{Cooling}$ = Electric energy savings for cooling, calculated above
CF = 0.0009474181

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

353 Average percentage improvement across 74 packaged service tune-up measures in the Ameren Missouri PY2019 Low Income Multifamily program.

3.4.7 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. 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 2009 Focus on Energy study of BPM blower motor savings in Wisconsin, which accounted for the effects of this behavioral impact.

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.

Note: as part of a Time of Sale measure, it is not appropriate to claim additional ECM fan savings due to installing a new furnace or CAC unit as ECM motors are now baseline for new furnaces and the SEER2/EER2 ratings of a CAC unit already account for this electrical load.

In an early replacement furnace situation, ECM fan heating savings can be claimed for the RUL of the existing furnace, and cooling savings can be claimed for the RUL of the CAC if an existing cooling unit is not replaced.

If a new CAC unit is installed in a home where the existing furnace is not replaced, heating ECM savings should only be claimed if it can be demonstrated that the new CAC motor will be used for the heating load.

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 furnace with a brushless permanent magnet (BPM) blower motor, also known by the trademark ECM, BLDC, and other names.

DEFINITION OF BASELINE EQUIPMENT

A furnace with a non-BPM blower motor. As part of the Code of Federal Regulations, energy conservation standards for covered residential furnace fans became effective on July 3, 2019 (10 CFR 430.32(y)). This code requirement effectively makes ECMs part of the baseline for New Construction (NC), Replace-on-Fail (ROF), Time-of-Replacement (TOS), and Early Replacement (EREP) scenarios.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6 years, which is the remaining life of existing furnaces.[354]

DEEMED MEASURE COST

The capital cost for this measure as a retrofit should be actual if known; if unknown, assume $350.[355] In cases of furnace early replacements, it is assumed the incremental cost of the ECM is $0.

LOADSHAPE

HVAC RES

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[354] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 150.

[355] Ibid., p. 151. 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.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh_{Heating\ Mode}$ = (1 - %_with_New_ASHP) * (400 kWh/year * HeatingEFLH / WisconsinHeatingEFLH) * HF * ISR
$\Delta kWh_{Cooling\ Mode}$ = (1 - %_with_New_Central_Cooling) * (70 kWh/year * CoolingEFLH / WisconsinCoolingEFLH) * HF * ISR
$\Delta kWh_{Auto\ Circulation}$ = (25 kWh/year * CoolingEFLH / WisconsinCoolingEFLH + 2,960 kWh/year * RT% - 30 kWh/year) * HF * ISR
$\Delta kWh_{Continous\ Circulation}$ = (25 kWh/year * CoolingEFLH / WisconsinCoolingEFLH + 2,960 kWh/year * RT% - 30 kWh/year) * HF * ISR

Where:

Parameter	Value
Wisconsin Cooling Savings kWh/year	70.00[356]
Cooling Savings All Systems	25.00[357]
Wisconsin Cooling EFLH	542.50[358]
Wisconsin Heating Savings kWh/year	400.00[359]
Wisconsin Heating EFLH	2,545.25[360]
Wisconsin Circulation Savings kWh/year	2,960.00[361]
RT=Percent additional run time factor	8.81%[362]
Standby losses	30[363]
Saint Louis Heating EFLH	2,009.00[364]
Saint Louis Cooling EFLH	1,215.00[365]
% with New Central Cooling	82%[366]
% with New ASHP	16%[367]
ISR	Actual, or if unknown, assume 100%[368]
HF	100%[369]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0004660805

NATURAL GAS SAVINGS

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356 Ameren Missouri HVAC Program Evaluation PY2017, page 41, https://www.efis.psc.mo.gov/Document/Display/14208
357 Ibid.
358 Ibid.
359 Ibid.
360 Ibid.
361 Ibid.
362 Ameren Missouri HVAC Program Evaluation PY2019, page 39, https://www.efis.psc.mo.gov/Document/Display/15876.
363 Ameren Missouri HVAC Program Evaluation PY2017, page 41, https://www.efis.psc.mo.gov/Document/Display/14208
364 Ibid.
365 Ibid.
366 Ameren Missouri HVAC Program Evaluation PY2019, https://www.efis.psc.mo.gov/Document/Display/15877, page 90.
367 Ibid.
368 Ameren Missouri HVAC Program Evaluation PY2020, https://www.efis.psc.mo.gov/Document/Display/13831, page 53.
369 Household Factor (HF) is assumed to be 100%. 65% multifamily value is not applicable for this measure, as savings should be based upon pressure drop in the system.

Δtherms[370] = - Heating Savings * 0.03412 / AFUE

Where:

0.03412 = Converts kWh to therms
AFUE = Efficiency of the Furnace
= Actual. If unknown assume 95%[371] if in new furnace or 64.4 AFUE%[372] if in existing furnace

Using defaults:

For new Furnace = - (430 * 0.03412) / 0.95
= - 15.4 therms
For existing Furnace = - (430 * 0.03412) / 0.644
= - 22.8 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

370 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.
371 Minimum efficiency rating from ENERGY STAR® Furnace Specification v4.0, effective February 1, 2013, https://www.energystar.gov/sites/default/files/specs/private/Final_Version_4.0_Specification.pdf; 'Final_Version_4.0_Specification.pdf', page 2.
372 Average nameplate efficiencies of all early replacement qualifying equipment in Ameren IL PY2003-PY2004.

3.4.8 Central Air Conditioner

DESCRIPTION

This measure characterizes:

1. TOS: The installation of a new residential sized (<= 65,000 Btu/hr) central air conditioning ducted split system meeting ENERGY STAR® efficiency standards presented below. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.
2. EREP: For the early replacement baseline to apply, program participants or installation contractors must provide documentation asserting that the existing units operated when turned on—whether or not they provided cooling—and the existing unit brand name and model number must be documented; or, if the nameplate is not readable, a photograph of the unit in context and the nameplate specifically must be provided. All other conditions will be considered TOS. The baseline SEER2 of the existing central air conditioning unit replaced: If the SEER2 of the existing unit is known and, the baseline SEER2 is the actual SEER2 value of the unit replaced. If the SEER2 of the existing unit is unknown, use assumptions in variable list below (SEER2_exist).

This measure was developed to be applicable to the following program types: TOS, NC, and 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 the minimum ENERGY STAR® efficiency level standards. For reference, the minimum ENERGY STAR® version 6.1 efficiency level standards are provided below[373]:

- Split system central air conditioners – 15.2 SEER2 and 12.0 EER2
- Single package central air conditioners – 15.2 SEER2 and 11.5 EER2
- Space constrained units – 13.4 SEER2[374]

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 6.1 specifications.

DEFINITION OF BASELINE EQUIPMENT

The baseline for the TOS measure is based on the current federal standard efficiency level[375]:

- Standard sized Split system air conditioners – 13.4 SEER2
- Standard sized Single-package air conditioners – 13.4 SEER2
- Space constrained air conditioners – 11.7 SEER2

Under the new federal standards, the M1 testing protocol was revised, resulting in a new SEER performance metric called SEER2. When quantifying energy savings, the SEER2 metric should be used for the existing, baseline, and new equipment. The following conversion formula can be used to convert between efficiency metrics:

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[373] ENERGY STAR Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment, v6.1, effective January 1, 2023, https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%206.1%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20%28Rev.%20January%20%202022%29.pdf; 'ENERGY STAR Version 6.1 Central Air Conditioner and Heat Pump Final Specification (Rev. January 2022).pdf', 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.

[374] The ENERGY STAR specification does not provide an efficiency level for space constrained products but this is a proposed level for this product type that the marketplace has developed solutions to meet.

[375] 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).

SEER2 = SEER * 0.96

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[376] for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years.[377]

Remaining life of existing equipment is assumed to be 6 years.[378]

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below:[379]

Efficiency Level (SEER2)	Incremental Cost
13.9	$111
14.4	$230
14.9	$453
15.4	$635
16.3	$861
16.8	$891
17.3	$921
19.2	$1,006
21.1	$1,120
22.4	$1,240
13.9	$111
14.4	$230
14.9	$453
15.4	$635

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.[380]

Efficiency Level (SEER2)	Full Retrofit Cost
13.9	$3,450
14.4	$3,569
14.9	$3,791
15.4	$3,973
16.3	$4,200
16.8	$4,229
17.3	$4,259
19.2	$4,345
21.1	$4,458
22.4	$4,579
13.9	$3,450
14.4	$3,569
14.9	$3,791

376 Baseline SEER and EER should be updated when new minimum federal standards become effective.
377 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, https://energizect.com/sites/default/files/documents/Measure%20Life%20Report%202007.pdf; 'Measure Life Report 2007.pdf'.
378 Assumed to be one third of effective useful life.
379 See 'CAC Costs 09.02.2024.xlsx'.
380 Ibid.

Efficiency Level (SEER2)	Full Retrofit Cost
15.4	$3,973

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $3,670.[381] This future cost should be discounted to present value using a 2.31% nominal societal discount rate, based on the ten year average (1/1/2014 – 12/31/2023) of the 10 year Treasury bond yield rates. [382]

LOADSHAPE
Cooling RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
Time of sale:

$\Delta kWh = ((FLH_{cool} * Capacity * (1/SEER2_{base} - 1/SEER2_{ee}))/1{,}000) * HF * ISR$

Early replacement:[383]

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

$=((FLH_{cool} * Capacity * (1/SEER2_{exist} - 1/SEER2_{ee}))/1{,}000) * HF * ISR$

ΔkWh for remaining measure life (next 12 years):

$= ((FLH_{cool} * Capacity * (1/SEER2_{base} - 1/SEER2_{ee}))/1{,}000) * HF * ISR$

Where:

FLH_{cool} = Full load cooling hours:[384]

Weather Basis (Ameren Missouri Average)	EFLHcool (Hours)
SF or MF	869
MFc (comprehensive envelope)	632[385]

Capacity = Size of new equipment in Btu/hr (note 1 ton = 12,000Btu/hr)
= Actual installed, or if actual size unknown 33,600Btu/hr for single-family buildings[386]

$SEER2_{base}$ = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh)[387]
= 13.4 SEER2 for standard sized units or 11.7 SEER2 for space constrained units[388]

$SEER2_{exist}$ = Seasonal Energy Efficiency Ratio of existing unit (kBtu/kWh)

[381] Ibid.
[382] 'Societal_Discount_Rate_Calculation_08082024.xlsx'.
[383] 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).
[384] Evaluation - Opinion Dynamics review PY2019. https://www.efis.psc.mo.gov/Document/Display/15876, page 30.
[385] Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.
[386] 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.
[387] SEER to SEER2 conversion factor: SEER2 = SEER * 96%. Conversion factor for SEER to SEER2 is used when converting an existing system that is rated in SEER to SEER2. This is to meet the DOE M1 CFR Standard beginning January 1, 2023. The efficiency levels of the existing, baseline, and efficient case must be expressed in SEER2 terms before applying formulas.
[388] Based on minimum federal standard effective 1/1/2023: 10 CFR 430.32(c)(5)

= Use actual SEER2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate the efficiency value based on the age of the existing equipment (up to a maximum of 30 years) to account for degradation over time.[389] If age is unknown, use 12 years.
= $SEER2 * (1-0.01)^{Age}$
If unknown, assume 8.9.[390], which is already adjusted to account for age-related degradation.

$SEER2_{ee}$ = Seasonal Energy Efficiency Ratio of ENERGY STAR® unit (kBtu/kWh)
= Actual installed or 15.2 if unknown.

HF = For Multifamily units, use a factor of 65% to convert residential single family to multifamily capacity. If actual capacity is used apply 100%.

ISR = In service rate
= Actual, or if unknown, assume 100%[391]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

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[389] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 112. Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018.docx'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).
[390] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 130.
[391] Ameren Missouri HVAC Evaluation: PY2020, https://www.efis.psc.mo.gov/Document/Display/13831, page 53.

3.4.9 Filter Cleaning or Replacement and Dirty Filter Alarms

DESCRIPTION

An air filter on a central forced air heating system is replaced prior to the end of its useful life with a new filter, resulting in a lower pressure drop across the filter. As filters age, the pressure drop across them increases as filtered medium accumulates. Replacing filters before they reach the point of becoming ineffective can save energy by reducing the pressure drop required by filtration, subsequently reducing the load on the blower motor.

This measure was developed to be applicable to the following program type: RET.

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

DEFINITION OF EFFICIENT EQUIPMENT

A new filter offering a lower pressure drop across the filter medium compared to the existing filter.

DEFINITION OF BASELINE EQUIPMENT

A filter that is nearing the end of its effective useful life, defined by having a pressure drop twice that of its original state.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 1 year[392] for a filter replacement and 5 years[393] for a dirty filter alarm.

DEEMED MEASURE COST

Actual material and labor cost should be used if known, since there is a wide range of filter types and costs. If unknown,[394] the cost of a fiberglass filter is assumed to be $7.33 and the cost of a pleated filter is assumed to be $15.66. If unknown, the cost of a dirty filter alarm is assumed to be $5.

LOADSHAPE

HVAC RES

Algorithm

CALCULATION OF SAVINGS

Electric energy savings are calculated by estimating the difference in power requirements to move air through the existing and new filter and multiplying by the anticipated operating hours of the blower during the heating season.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kWh\_{heating} + kWh\_{cooling}$$

$$kWh\_{heating} = \%Heating * kW_{motor} * EFLH_{heat} * EI * (1 - Leakage) * ISR$$

$$kWh\_{cooling} = \%AC * kW_{motor} * EFLH_{cool} * EI * (1 - Leakage) * ISR$$

[392] Many manufacturers suggest replacing filters more often than an annual basis, however this measure assumes that a filter will generally last one full heating season before it needs replacement.

[393] CPUC Support Tables: Effective Useful Life and Remaining Useful Life. Air Filter Alarm. Accessed on June 11, 2024. https://www.caetrm.com/cpuc/table/effusefullife/

[394] Assumes an average price of $1.08 for fiberglass and $9.41 for pleated, plus $6.25 in labor (based on 15 minutes, including portion of travel time, and $25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per Annual Wage Order No. 23 documents published by the Missouri Department of Labor). Average filter costs sourced from “Air Filter Testing, Listing, and Labeling,” Docket #12-AAER-2E prepared for the California Energy Commission, July 23, 2013.

Where:

Factor	Term	School Value
%Heating	Fraction of participants with electric heating	Actual
%AC	Fraction of participants with central cooling	Actual
kW_{motor}	Average motor full load electric demand (kW) – Kits	0.5[395]
	Average motor full load electric demand (kW) – MFLI	0.43
	Average motor full load electric demand (kW) – Other Programs	0.377[396]
$EFLH_{heat}$	Equivalent Full Load Hours (EFLH) Heating (hours/year) – SF or MF	1496[397]
	Equivalent Full Load Hours (EFLH) Heating (hours/year) - MFc (comprehensive envelope)	510[398]
$EFLH_{cool}$	Equivalent Full Load Hours (EFLH) Cooling (hours/year) - SF or MF	869[399]
	Equivalent Full Load Hours (EFLH) Cooling (hours/year) - MFc (comprehensive envelope)	632[400]
EI	Efficiency Improvement (%)	10%[401]
Leakage	% Homes outside Service Territory – Kits	28%[402]
	% Homes outside Service Territory – Other Programs	0%
ISR	In Service Rate – School Kits	Actual, or if unknown, assume 44%[403]
	In Service Rate – Appliance Recycling Program	Actual, or if unknown, assume 9%[404]
	In Service Rate – MFIE Kits	Actual, or if unknown, assume 100%[405]
	In Service Rate – MFMR and Single Family Income-Eligible	Actual, or if unknown, assume 57.89%[406]
	In Service Rate – Other Programs	Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0004660805

395 Ameren Missouri EE Kits Evaluation PY2018, page 41, https://www.efis.psc.mo.gov/Document/Display/15870.
396 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 232. Typical blower motor capacity for gas furnace is ¼ to ¾ HP. Midpoint is ½ HP. ½ HP * 0.746 (kW/hp) = 0.377kW.
397 Ameren Missouri EE Kits Evaluation PY2018, page 41, https://www.efis.psc.mo.gov/Document/Display/15870.
398 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.
399 Ameren Missouri EE Kits Evaluation PY2018, page 41, https://www.efis.psc.mo.gov/Document/Display/15870.
400 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.
401 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 233. Based on Energy.gov website; "Maintaining Your Air Conditioner", which states that replacing a dirty air filter with a clean one can lower total air conditioner energy consumption by 5-15%. See https://www.energy.gov/energysaver/maintaining-your-air-conditioner; 'Maintaining Your Air Conditioner _ Department of Energy.pdf'.
402 Ameren Missouri Energy Efficient Kits Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 77.
403 Ibid.
404 Ameren Missouri Appliance Recycling Evaluation: PY2019, https://www.efis.psc.mo.gov/Document/Display/15876, page 95.
405 Ameren Missouri EE Kits PY18 Evaluation, https://www.efis.psc.mo.gov/Document/Display/15870, page 41.
406 Ameren Missouri Community Savers Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/36053, page 27.

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

3.4.10 Packaged Terminal Air Conditioner (PTAC) and Packaged Terminal Heat Pump (PTHP)

DESCRIPTION

A PTAC is a packaged terminal air conditioner that cools and provides heat through an electric resistance heater (heat strip). A PTHP is a packaged terminal heat pump. A PTHP uses its compressor year-round to heat or cool. In warm weather, it efficiently captures heat from inside a space and pumps it outside for cooling. In cool weather, it captures heat from outdoor air and pumps it into a space, adding heat from electric heat strips as necessary to provide heat.

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

This measure characterizes:

1. TOS: the purchase and installation of a new efficient PTAC or PTHP.
2. EREP: For the early replacement baseline to apply, program participants or installation contractors must provide documentation asserting that the existing units operated when turned on—whether or not they provided cooling—and the existing unit brand name and model number must be documented; or, if the nameplate is not readable, a photograph of the unit in context and the nameplate specifically must be provided. 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. The measure is only valid for non-fuel switching installations – for example replacing a cooling only PTAC with a PTHP can currently not use the TRM.

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 PTACs or PTHPs that exceed baseline efficiencies.

DEFINITION OF BASELINE EQUIPMENT

TOS: the baseline condition is defined by the Code of Federal Regulations at 10 CFR 431.97(c), section §431.97.

EREP: the baseline is the existing PTAC or PTHP for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[407]

Remaining life of existing equipment is assumed to be 5 years.[408]

DEEMED MEASURE COST

TOS: The incremental capital cost for this equipment is estimated to be $84/ton.[409]

EREP: 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 unknown, assume $1,047 per ton.[410]

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton.[411] This future cost should be discounted to present value using a 2.31% nominal societal discount rate, based on the ten year average (1/1/2014 – 12/31/2023) of the 10 year Treasury bond yield rates. [412]

LOADSHAPE

Cooling RES
Heating RES

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[407] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007, https://energizect.com/sites/default/files/documents/Measure%20Life%20Report%202007.pdf; 'Measure Life Report 2007.pdf', page 1-4.
[408] Standard assumption of one third of effective useful life.
[409] DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation.
[410] Based on DCEO – IL PHA Efficient Living Program data.
[411] Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.
[412] 'Societal_Discount_Rate_Calculation_08082024.xlsx'.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings for PTACs and PTHPs should be calculated using the following algorithms

Time of sale:

ΔkWh = [((EFLH$_{cool}$ * Capacity$_{cool}$ * (1/SEER2$_{base}$ - 1/SEER2$_{ee}$)) / 1000) + ((EFLH$_{heat}$ * Capacity$_{heat}$ * (1/HSPF2$_{base}$ - 1/HSFP2$_{ee}$)) / 1,000)] * ISR

Early replacement:[413]

ΔkWh for remaining life of existing unit:

= [((EFLH$_{cool}$ * Capacity$_{cool}$ * (1/SEER2$_{exist}$ - 1/SEER2$_{ee}$)) / 1000) + ((EFLH$_{heat}$ * Capacity$_{heat}$ * (1/HSPF2$_{exist}$ - 1/HSFP2$_{ee}$)) / 1,000)] * ISR

ΔkWh for remaining measure life:

=[((EFLH$_{cool}$ * Capacity$_{cool}$ * (1/SEER2$_{base}$ - 1/SEER2$_{ee}$)) / 1000) + ((EFLH$_{heat}$ * Capacity$_{heat}$ * (1/HSPF2$_{base}$ - 1/HSFP2$_{ee}$)) / 1,000)] * ISR

Where:

Capacity$_{heat}$ = Heating capacity of the unit in Btu/hr
= Actual

EFLH$_{heat}$ = Equivalent Full Load Hours for heating.
= Custom input if program or regional evaluation results are available, otherwise, per the following table:

Weather Basis (Ameren Missouri Average)	EFLH$_{heat}$[414]
SF or MF	1040
MFc (comprehensive envelope)	355

HSPF2$_{ee}$ = HSPF rating of new equipment
= Actual installed

HSPF2$_{base}$ =Heating System Performance Factor of baseline unit (kBtu/kWh)

Equipment Type	Unit Size	Federal Regulations Minimum Efficiency (HSPF)
PTHP (Heating mode)	Standard Sized	(3.7 – (0.052 * Capacity$_{heat}$ / 1,000)) * 3.41
PTHP (Heating mode)	Non-Standard Size*	(2.9 – (0.026 * Capacity$_{heat}$ / 1,000)) * 3.41

HSPF2$_{exist}$ = Actual HSPF rating of existing equipment. If unknown, assume:

Existing Equipment Type	HSPF2$_{exist}$
Electric resistance heating (PTAC)	3.412[415]
PTHP	5.44[416]

[413] 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).

[414] Base values reported in *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015, Ameren. Illinois were adjusted to fit Missouri climate zones by a comparison of relative annual heating and cooling degree hours (base 65). See '3.4.8 EFLH 06022016.xlsx' for derivation. 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.

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

[416] This is estimated based on finding the average HSPF/SEER ratio from the AHRI directory data (using the least efficient models – SEER 12 and SEER 13) – 0.596 and applying to the average nameplate SEER rating of all early replacement qualifying equipment in Ameren PY2003-PY2004. This estimation methodology appears to provide a result within 10% of actual HSPF.

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr.[417]
= Actual installed
$SEER2_{ee}$ = SEER rating of new equipment
= Actual installed[418]
$SEER2_{base}$ = SEER2 rating of the baseline unit (kBtu/kWh). When using the formulas in the table below, convert the baseline EER to SEER2 using the EER conversion formula.[419]

Equipment Type	Unit Size	Federal Regulations Minimum Efficiency (EER)
PTAC (Cooling mode)	Standard Sized	$14.0 – (0.300 * Capacity_{cool} / 1,000)$
PTAC (Cooling mode)	Non-Standard Size*	$10.9 – (0.213 * Capacity_{cool} / 1,000)$
PTHP (Cooling mode)	Standard Sized	$14.0 – (0.300 * Capacity_{cool} / 1,000)$
PTHP (Cooling mode)	Non-Standard Size*	$10.8 – (0.213 * Capacity_{cool} / 1,000)$

* Non-Standard Size apply only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.

$SEER2_{exist}$ = Actual SEER rating of existing equipment. If unknown, assume:

Existing Cooling System	$SEER2_{exist}$[420]
PTHP	6.91
PTAC	6.53

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling.
= Custom input if program or regional evaluation results are available, otherwise, per the following table.[421]

Weather Basis (Ameren Missouri Average)	$EFLH_{cool}$
SF or MF	617
MFc (comprehensive envelope)	449

ISR = In-service rate. Actual, or if unknown, assume 100%[422]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

$$\Delta kW = \Delta kWh_{Cooling} * CF$$

Where:

$\Delta kWh_{Cooling}$ = Electric energy savings for cooling, calculated above
CF = 0.0009474181

NATURAL GAS ENERGY SAVINGS

N/A

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417 1 Ton = 12 kBtu/hr.
418 If only an EER2 rating is available, use the following conversion equation to estimate SEER2; $SEER = (1.12 + (1.2544 - 0.08 * EER)^{0.5}) / 0.04$. This is the observse of $EER = (-0.02 * SEER^2) + (1.12 * SEER)$. From Wassmer, M. (2003), “A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations,” (Masters thesis), University of Colorado at Boulder.
419 Ibid.
420 ASHP existing efficiency assumes degradation and is sourced from the Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015. CAC assumed to follow the same trend in degradation as the ASHP: 9.12 SEER nameplate to 7.2 (6.91 SEER2) operations SEER represents degradation to 78.9% of nameplate. 78.9% of 8.6 SEER CAC nameplate gives an operational SEER of 6.8 (6.53 SEER2).
421 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.
422 Ameren Missouri HVAC Evaluation: PY2020, https://www.efis.psc.mo.gov/Document/Display/13831, page 53.

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

3.4.11 Room Air Conditioner

DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets the ENERGY STAR® minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum federal standard efficiency ratings presented below:[423]

Product Type and Class (Btu/hr)		Federal Standard with louvered sides (CEER) [424]	Federal Standard without louvered sides (CEER)	ENERGY STAR® v4.0 / CEE Tier 1 with louvered sides (CEER) [425]	ENERGY STAR® v4.0 / CEE Tier 1 without louvered sides (CEER)	CEE Tier 2 (CEER)[426]
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		

This measure was developed to be applicable to the following program type: TOS and 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® efficiency standards presented above.

DEFINITION OF BASELINE EQUIPMENT

For programs other than low-income programs, the baseline assumption is a new room air conditioning unit that meets the current minimum federal efficiency standards presented above.

For low income programs, 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years.[427]

For low income programs, since the baseline unit is assumed to be purchased from the secondary market, it is assumed that the remaining life of the baseline unit is 6 years and would need to be replaced with another unit from the secondary market at that point.[428]

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[423] Side louvers that 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. https://www.energystar.gov/products/heating_cooling/air_conditioning_room/key_product_criteria

[424] See DOE's Appliance and Equipment Standards for Room AC;

[425] ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements

[426] 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

[427] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, https://energizect.com/sites/default/files/documents/Measure%20Life%20Report%202007.pdf; 'Measure Life Report 2007.pdf', page 1-3.

[428] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 68.

DEEMED MEASURE COST

For programs other than low-income programs, 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.[429]

For low income programs, the actual full cost of the ENERGY STAR® unit should be used. If unavailable assume $300.[430] If a CEE Tier 2 unit is installed assume $508.[431]

LOADSHAPE

Cooling RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = (FLH_{RoomAC} * Btuh * (1/CEER_{base} - 1/CEER_{ee})) / 1,000$

Where:

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

Weather Basis (City based upon)	Hours[432]
St Louis, MO	860 for primary use and 556 for secondary use

Btu/H = Size of unit
= Actual. If unknown assume 8,500 Btu/hr [433]

$CEER_{base}$ = Efficiency of baseline unit
= For programs other than low-income programs, as provided in tables above
= For low income programs, actual CEER of the existing unit; if unknown, assume 7.7[434]

$CEER_{ee}$ = Efficiency of ENERGY STAR® unit
= Actual. If unknown assume minimum qualifying standard as provided in tables above

ISR = Actual, or if unknown, reference values in the table below dependent on program type

Program Type	ISR
TOS[435]	97%
SFIE[436]	98%

429 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 41. CEE Tier 1 cost based on field study conducted by Efficiency Vermont and Tier 2 based on professional judgement.
430 Ibid.
431 Consistent with Non IQ version of the measure.
432 Primary is based upon Ameren Missouri PY2013 CoolSavers Evaluation data, Secondary is based upon Ameren Missouri Efficient Products PY2016 Evaluation, https://www.efis.psc.mo.gov/Document/Display/17349, page 64.
433 Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008, https://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/122_SPWG%20Room%20%20AC%20Evaluation%20FINALReport%20June%2023%20ver7.pdf; '122_SPWG Room AC Evaluation FINALReport June 23 ver7.pdf'.
434 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 70.
435 Ameren Missouri PY18 Efficient Products Evaluation, https://www.efis.psc.mo.gov/Document/Display/15869, page 28.
436 Ameren Missouri Efficient Products Evaluation PY2016, https://www.efis.psc.mo.gov/Document/Display/17349, page 63.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, as calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[437]

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[437] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors"for residential cooling end-use.

3.4.12 Ground Source Heat Pump

DESCRIPTION
A heat pump provides heating or cooling by moving heat between indoor and the ground.

This measure characterizes:

1. TOS: The installation of a new residential sized ground source heat pump. 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.
2. EREP: The early removal of functioning electric heating and cooling systems from service, prior to its natural end of life, and replacement with a new high efficiency ground source heat pump unit. To qualify as early replacement, the existing unit must be operational when replaced. If the SEER of the existing unit is known, the baseline SEER is the actual SEER value of the unit replaced, and if unknown use assumptions in the variable list below ($SEER2_{exist}$ and $HSPF2_{exist}$). If the operational status of the existing unit is unknown, use TOS assumptions.

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

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

DEFINITION OF EFFICIENT EQUIPMENT
A new residential sized ground source heat pump with specifications to be determined by program.

DEFINITION OF BASELINE EQUIPMENT
The baseline for the TOS measure is federal standard efficiency level as of: 14.3 SEER2 and 7.5 HSPF2 when replacing an existing air source heat pump or existing ground source heat pump, and 13.4 SEER2 and 3.41 HSPF2 when replacing a central air conditioner and electric resistance heating.

For the early replacement baseline to apply, program participants or installation contractors must provide documentation asserting that the existing units operated when turned on—whether or not they provided cooling—and the existing unit brand name and model number must be documented; or, if the nameplate is not readable, a photograph of the unit in context and the nameplate specifically must be provided. The baseline for the early replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 25 years.[438]

For early replacement, the remaining life of existing equipment is assumed to be 6 years for GSHP, ASHP and CAC and 25 years for electric resistance.

DEEMED MEASURE COST
New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump should be used (default of $3957 per ton),[439] minus the assumed installation cost of the baseline equipment ($6562 + $600 per ton for ASHP[440] or $2011 for a new baseline 80% AFUE furnace[441] and $3,338 for new baseline Central AC replacement [442]).

Early Replacement: The actual full installation cost of the Ground Source Heat Pump should be used (default of $3957 per ton).
The assumed deferred cost 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 and $3,670 for new baseline Central AC replacement.[443] This future cost should be discounted to present value using a 2.31% nominal societal discount rate, based on the ten year average (1/1/2014 – 12/31/2023) of the 10 year Treasury bond yield rates. [444]

LOADSHAPE

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438 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, p. 166. System life of indoor components as per DOE estimate (see 'Geothermal Heat Pumps Department of Energy.htm'). The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.
439 Based on data provided in 'Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives'.
440 Full install ASHP costs are based upon data provided by Ameren. See 'ASHP Costs_06242022'.
441 See 'Technical Standard Document_APPENDIX_E.pdf'.
442 See 'CAC Costs 09.02.2024.xlsx'.
443 All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.
444 'Societal_Discount_Rate_Calculation_08082024.xlsx'.

Cooling RES
Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

TOS:

$\Delta kWh = [((EFLH_{cool} * Capacity_{cool} * (1/EER2_{base} - 1/EER2_{ee}) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF2_{base} - 1/HSFP2_{ee}) / 1000)] * ISR$

EREP:[445]

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

$= [((EFLH_{cool} * Capacity_{cool} * (1/EER2_{exist} - 1/EER2_{ee}) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF2_{exist} - 1/HSFP2_{ee}) / 1000)] * ISR$

ΔkWh for remaining measure life (next 12 years if replacing an ASHP or GSHP):

$= [((EFLH_{cool} * Capacity_{cool} * (1/EER2_{base} - 1/EER2_{ee}) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF2_{base} - 1/HSFP2_{ee}) / 1000)] * ISR$

Where:

$EFLH_{cool}$ = Equivalent full load hours of air conditioning:[446]

Weather Basis (City based upon)	$EFLH_{cool}$ (Hours)
St Louis, MO	869

$Capacity_{cool}$ = Cooling capacity of air source heat pump (Btu/hr)
= Actual (1 ton = 12,000Btu/hr)

$EER2_{exist}$ = Seasonal Energy Efficiency Ratio of existing unit (kBtu/kWh)
= Use actual SEER2[447] rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate the efficiency value based on the age of the existing equipment (up to a maximum of 30 years) to account for degradation over time.[448] If age is unknown, use 12 years.
$= SEER2 * (1-0.01)^{Age}$
If rated efficiency is unknown, use defaults provided below, which should not be further adjusted to account for age-related degradation:

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445 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).
446 PY2019 Evaluation Report, https://www.efis.psc.mo.gov/Document/Display/15876, page 30.
447 Part load EER2 is paired with SEER2exist, consistent with the approach presented in section 3.4.2, Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, p. 508.
448 Ibid., page 112. Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018.docx'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

Existing Cooling System	$SEER2_{exist}$
Air Source Heat Pump	6.91[449]
Ground Source Heat Pump	13.4[450]
Central AC	6.53
No central cooling[451]	Let '$1/SEER2_{exist}$' = 0

$EER2_{base}$ = Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)
= 14.3 if replacing air source heat pump or ground source heat pump; 13.4 if replacing central air conditioner

$EER2_{ee}$ = Seasonal Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/kWh)
= Actual

$EFLH_{heat}$ = Equivalent full load hours of heating
= Dependent on location:[452]

Weather Basis (City based upon)	$EFLH_{heat}$ (Hours)
St Louis, MO	1496

$Capacity_{heat}$ = Heating Capacity of Air Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000Btu/hr)

$HSPF2_{exist}$ = Heating System Performance Factor of existing heating system (kBtu/kWh)
= Use actual HSPF2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate the efficiency value based on the age of the existing equipment (up to a maximum of 30 years) to account for degradation over time.[453] If age is unknown, use 12 years.
= $HSPF2 * (1-0.01)^{Age}$
= If rated efficiency is unknown, use defaults provided below, which should not be further adjusted to account for age-related degradation: [454]

Existing Heating System	$HSPF2_{exist}$
Air Source Heat Pump	4.91
Ground Source Heat Pump	7.5
Electric Resistance	3.41

$HSPF2_{base}$ = Heating System Performance Factor of baseline Air Source Heat Pump (kBtu/kWh)
= 7.5 if replacing air source heat pump or ground source heat pump; 3.41 if replacing electric resistance heating

$HSFP2_{ee}$ = Heating System Performance Factor of efficient Air Source Heat Pump (kBtu/kWh)

ISR = In-service rate. Actual, or if unknown, assume 100%[455]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

TOS:

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

Where:

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[449] ASHP existing efficiency assumes degradation and is sourced from the Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015. CAC assumed to follow the same trend in degradation as the ASHP: 9.12 SEER nameplate to 7.2 (6.91 SEER2) operations SEER represents degradation to 78.9% of nameplate. 78.9% of 8.6 SEER CAC nameplate gives an operational SEER of 6.8 (6.53 SEER2).

[450] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 169.

[451] 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.

[452] PY2019 Residential Evaluation Report, https://www.efis.psc.mo.gov/Document/Display/15876, page 30.

[453] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 112. Justification for degradation factors can be found on page 14 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018.docx'. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

[454] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 171.

[455] Ameren Missouri HVAC Evaluation: PY2020, https://www.efis.psc.mo.gov/Document/Display/13831, page 53.

ΔkWh	= Electric energy savings, as calculated above
CF	= Summer peak coincidence demand (kW) to annual energy (kWh) factor
	= 0.0009474181

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

3.5 Lighting

3.5.1 LED Screw Based Omnidirectional Bulb

DESCRIPTION

This measure provides savings assumptions for LED screw-based omnidirectional (e.g., A-Type) lamps installed in a known location (i.e., residential and in-unit interior or exterior) or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program or efficiency kit), an unknown residential location. For upstream programs, utilities should develop an assumption of the Residential v Commercial split and apply the relevant assumptions to each portion.

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations required that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in effect making the baseline equivalent to a current day CFL. In 2019, the Department of Energy issued a final determination and clarified that a) the EISA backstop provision had not been triggered and therefore b) the efficiency standard would not change in 2020. In May 2022, DOE reversed this decision by issuing a final rule that expanded the General Service Lamp (GSL) and General Service Incandescent Lamp (GSIL) definitions and reinstated the 45 lumen per watt backstop provision with phased enforcement between January 2023 and July 2023.[456]

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this measure to apply, new lamps must be ENERGY STAR® labeled based upon the ENERGY STAR® specification v2.0 which became effective on 1/2/2017.[457]

Qualification could also be based on the Design Light Consortium's qualified product list.[458]

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.

No savings are claimed for non-income qualified programs unless via direct install programs.

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DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be two years for Direct Install in non-income eligible populations and eight years for income eligible populations .[459]

DEEMED MEASURE COST

The deemed measures cost for a LED screw based omnidirectional bulb is $1.45 per bulb.[460]

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[456] DOE 87 FR 27439

[457] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20AUG-2016.pdf; 'ENERGY STAR Lamps V2_0 Revised AUG-2016.pdf'.

[458] https://www.designlights.org/QPL.

[459] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 327.

[460] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 329.

LOADSHAPE
Lighting RES
Lighting BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = (Watt_{Base} - Watt_{EE}) * ISR * (1 - LKG) * Hours * WHF / 1{,}000$

Where:

$Watts_{Base}$ = Based on lumens of LED bulb installed. If lumens of LED bulb are unknown, refer to table below.
$Watts_{EE}$ = Actual wattage of LED purchased / installed - If unknown, use default provided below:[461]

Minimum Lumens	Maximum Lumens	LED Wattage (WattsEE)	Baseline (WattsBase)	Delta Watts (WattsEE)
310	399	4.0	25	21.0
400	749	6.6	29	22.4
750	899	9.6	43	33.4
900	1,399	13.1	53	39.9
1,400	1,999	16.0	72	56.0
2,000	2,999	21.8	150	128.2
3,000	3,299	28.9	200	171.1

LKG = leakage rate (program bulbs installed outside Ameren Missouri's service area)
= Actual, or if unknown, assume 0%[462]

ISR = In Service Rate, the percentage of units rebated that are actually in service. Actual, or if unknown, assume:

Program	Discounted In Service Rate (ISR)
Direct Install (MFLI) [463]	98.2%
Efficiency Kit (MF)[464]	100%
Low Income Kits	90%
Pay As You Save[465]	87%

Hours = Average hours of use per year for bulbs in residential homes. Use custom value or table below.

[461] Ibid., page 328.
[462] Assumed based on program delivery channels.
[463] Ameren Missouri Community Savers Evaluation: PY2018, . https://www.efis.psc.mo.gov/Document/Display/36053, page 17.
[464] Ameren Missouri Efficient Kits Impact and Process Evaluation: Program Year 2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 38.
[465] Ameren Missouri Pay As You Save (PAYS®) Evaluation: PY2022 Participant Survey

Program	HOU Res
Residential	995.18[466]
Efficient Kits	995.18
Income Eligible RES	674.18[467]
MFMR	693.50[468]

$WHFe$ = Waste Heat Factor for energy to account for the impact from reducing waste heat from efficient lighting on electric cooling and heating loads in residential homes.
= 0.99 if unknown[469]

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating, see calculation of heating penalty in that section).
= 1 - ((HF / ηHeat) * %ElecHeat).
= If unknown assume 0.88[470]

Where:

HF = Heating Factor or percentage of light savings that must now be heated
= 53%[471] for interior or unknown location
= 0% for exterior or unheated location

$\eta Heat_{Electric}$ = Efficiency in COP of Heating equipment
= Actual - If not available, use:[472]

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[473]	N/A	N/A	1.28

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[474]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting

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466 Ameren Missouri Lighting Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/15873, page 36.
467 Ameren Missouri Community Savers Evaluation PY2018 workpapers- Weighted Avg. HOU from ADM workpapers.
468 ADM 2017 Community Savers EM&V
469 Ameren Missouri PY2014 Evaluation, https://www.efis.psc.mo.gov/Document/Display/14194, page 45.
470 Calculated using defaults: 1-((0.53/1.57) * 0.35) = 0.88.
471 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington). These results were judged to be equally applicable to Missouri.
472 These default system efficiencies are based on the applicable minimum federal standards. In 2006 and 2015, 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.
473 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.
474 Average (default) value of 35% electric space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[475]
Building without cooling or exterior	1.0
Unknown	1.11[476]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001492529 for Lighting RES (Residential)

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes:[477]

$\Delta Therms = -((Watts\_{Base} – Watts_{EE}) / 1,000 * ISR * Hours * HF * 0.03412) / \eta Heat * \%GasHeat$

Where:

HF = Heating Factor or percentage of light savings that must now be heated
= 53%[478] for interior or unknown location
= 0% for exterior or unheated location
0.03412 =Converts kWh to therms
$\eta Heat_{Gas}$ = Efficiency of heating system
= 71%[479]
%GasHeat = Percentage of heating savings assumed to be natural gas

Heating fuel	%GasHeat
Electric	0%
Natural Gas	100%
Unknown	65%[480]

MEASURE CODE:

[475] The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)), and it is based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington)). The estimate also assumes typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * $SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP). Results of the Iowa study are assumed to be applicable to Missouri.

[476] The value is estimated at 1.11 (calculated as 1 + (0.91*(0.34 / 2.8)), which is based on assumption that 91% of homes have central cooling (based on 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls') .

[477] Negative value because this is an increase in heating consumption due to the efficient lighting.

[478] This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington). Results of the Iowa study are judged to be equally applicable to Missouri.

[479] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). See reference https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 15 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

[480] Average (default) value of 65% gas space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

3.5.2 LED Specialty Lamp

DESCRIPTION

This measure provides savings assumptions for LED directional, decorative, and globe lamps when the LED is installed in a known location (i.e., residential and in-unit interior or exterior) or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program or efficiency kit), an unknown residential location. For upstream programs, utilities should develop an assumption of the Residential v Nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations required that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in effect making the baseline equivalent to a current day CFL. In 2019, the Department of Energy issued a final determination and clarified that a) the EISA backstop provision had not been triggered and therefore b) the efficiency standard would not change in 2020. In May 2022, DOE reversed this decision by issuing a final rule that expanded the General Service Lamp (GSL) and General Service Incandescent Lamp (GSIL) definitions and reinstated the 45 lumen per watt backstop provision with phased enforcement between January 2023 and July 2023.[481]

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

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 based upon the ENERGY STAR® specification v2.0 which became effective on 1/2/2017. [482] Qualification could also be based on the Design Light Consortium's qualified product list.[483]

DEFINITION OF BASELINE EQUIPMENT

Starting August 1, 2023, the EISA backstop provision became effective, limiting the sale, manufacture, and import of non-compliant lamps. Therefore, the baseline condition for this measure is a reflection of the 2022 DOE final rule reinstating the 45 lumen per watt backstop provisions for all GSL and GSILs between 310 and 3,300 lumens. All other lamps, i.e., those below 310 lumens and above 3,300 lumens, the baseline condition is a reflection of products available in the market and standards agreed upon in practice.

No savings are claimed for non-income qualified programs unless via direct install programs.

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.

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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be two years for Direct Install in non-income eligible populations and eight years for income eligible populations .[484]

DEEMED MEASURE COST

The deemed measures cost for a specialty LED is $1.66 per lamp.[485]

LOADSHAPE

Lighting RES
Lighting BUS

Algorithm

[481] DOE 87 FR 27439.
[482] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20AUG-2016.pdf; 'ENERGY STAR Lamps V2_0 Revised AUG-2016.pdf'.
[483] https://www.designlights.org/QPL.
[484] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 311.
[485] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 311.

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (Watt_{Base} - Watt_{EE}) * ISR * (1 - LKG) * Hours * WHF / 1{,}000$$

Where:

$Watts_{Base}$ = Based on bulb type and lumens of LED bulb installed. See tables below.
$Watts_{EE}$ = Actual wattage of LED purchased / installed - If unknown, use default provided below:

Decorative Lamps – ENERGY STAR Minimum Luminous Efficacy = 65Lm/W for all lamps:

Bulb Type	Minimum Lumens	Maximum Lumens	LED Wattage ($Watts_{EE}$)	Baseline ($Watts_{Base}$)	Delta Watts (WattsEE)
Omni-Directional 3-Way	1,100	1,999	14.7	100	85.3
	2,000	2,700	22.6	150	127.4
Globe (medium and intermediate bases less than 750 lumens)	310	349	3.0	25	22
	350	499	4.7	40	35.3
	500	574	5.7	60	54.3
	575	649	6.5	75	68.5
	650	1,000	8.2	100	91.8
Globe (candelabra bases less than 1050 lumens)	310	349	3.5	25	21.5
	350	499	4.4	40	35.6
	500	574	5.5	60	54.5
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	310	499	4.3	40	35.7
	500	800	5.8	60	54.2
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	310	499	4.2	40	35.8
	500	650	5.5	60	54.5
Decorative (Shape ST)	310	499	6.5	40	33.5
	500	999	8.8	60	51.2
	1000	1500	10.0	100	90.0
Decorative (Shape S)	310	340	2.25	25	22.8

Directional Lamps - ENERGY STAR Minimum Luminous Efficacy = 70Lm/W for <90 CRI lamps and 61 Lm/W for >=90CRI lamps.

Directional R, BR, and ER lamp types:[486]

[486] From pg. 13 of the ENERGY STAR Specification for lamps v2.1

Bulb Type	Minimum Lumens	Maximum Lumens	LED Wattage ($Watts_{EE}$)	Baseline ($Watts_{Base}$)	Delta Watts (WattsEE)
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	43
	650	899	10.7	75	64.3
	900	1,049	13.9	90	76.1
	1,050	1,199	13.8	100	86.2
	1,200	1,499	15.9	120	104.1
	1,500	1,999	18.9	150	131.1
	2,000	3,299	27.3	250	222.7
Reflector lamp types with medium screw bases (PAR16, R14, R16, etc.) w/ diameter <2.25" (*see exceptions below)	310	374	4.6	35	30.4
	375	600	6.4	50	43.6
*BR30, BR40, or ER40	650	949	9.3	65	55.7
	950	1,099	12.7	75	62.3
	1,100	1,399	14.4	85	70.6
	1,400	1,600	16.6	100	83.4
	1,601	1,800	22.2	120	97.8
*R20	450	524	6.0	40	34.0
	525	750	7.1	45	37.9
*MR16	310	324	3.8	20.0	16.2
	325	369	4.8	25.0	20.2
	370	400	4.9	25.0	20.1

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.[487] 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.[488]

WattsBase = 375.1 – 4.355(D) – (227,800 – (937.9 * D) – (0.9903 * D^2) – (1,479 *BA) – (12.02 * D * BA) + (14.69 * (BA^2)) - 16,720 * ln(CBCP))^0.5

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)
BA = Beam angle
CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by ENERGY STAR:

[487] See 'ESLampCenterBeamTool.xlsx'.
[488] The ENERGY STAR Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

Diameter	Permitted Wattages
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 ($Watts_{Base}$)	Delta Watts (WattsEE)
Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	310	399	4.0	25	21.0
	400	749	6.6	29	22.4
	750	899	9.6	43	33.4
	900	1,399	13.1	53	39.9
	1,400	1,999	16.0	72	56.0

LKG = leakage rate (program bulbs installed outside Ameren Missouri's service area)
= Actual, or if unknown, assume 0%[489]

ISR = In Service Rate, the percentage of units rebated that are actually in service. Actual, or if unknown, assume:

Program	Discounted In Service Rate (ISR)
Direct Install (MFLI) [490]	98.2%
Efficiency Kit (MF)[491]	100%
Low Income Kits	90%
Pay As You Save[492]	87%

Hours = Average hours of use per year for bulbs in residential homes. Custom, or if unknown assume 1,314[493] for exterior, or or if interior use table below.

Program	HOU Res
Residential	995.18[494]
Efficient Kits	995.18
Income Eligible RES	674.18[495]
MFMR	693.50[496]

WHFe = Waste Heat Factor for energy to account for the impact from reducing waste heat from efficient lighting on electric cooling and heating loads in residential homes.
= 0.99 if unknown[497]

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[489] Assumed based on program delivery channels.
[490] Ameren Missouri Community Savers Evaluation: PY2018, . https://www.efis.psc.mo.gov/Document/Display/36053, page 17.
[491] Ameren Missouri Efficient Kits Impact and Process Evaluation: Program Year 2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 38.
[492] Ameren Missouri Pay As You Save (PAYS®) Evaluation, https://www.efis.psc.mo.gov/Document/Display/17591, page 7.
[493] Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. Average daily HOU for efficient bulbs is listed as 3.6 for outside bulbs and a weighted (by inventory) average of 1.99 for inside spaces. Unknown location is weighted average (by inventory) of all bulbs. See 'MO Lamp Hours.xlsx' for calculations.
[494] Ameren Missouri Lighting Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/15873, page 36.
[495] Ameren Missouri Community Savers Evaluation PY2018 workpapers- Weighted Avg. HOU from ADM workpapers.
[496] ADM 2017 Community Savers EM&V, https://www.efis.psc.mo.gov/Document/Display/28281, page 3-4.
[497] Ameren Missouri PY2014 Evaluation, https://www.efis.psc.mo.gov/Document/Display/14194, page 45.

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating, see calculation of heating penalty in that section).
= 1 - ((HF / ηHeat) * %ElecHeat).
= If unknown assume 0.88[498]

Where

HF = Heating Factor or percentage of light savings that must now be heated
= 53%[499] for interior or unknown location
= 0% for exterior or unheated location

$\eta Heat_{Electric}$ = Efficiency in COP of Heating equipment
= Actual - If not available, use:[500]

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[501]	N/A	N/A	1.28

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[502]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[503]
Building without cooling or exterior	1.0
Unknown	1.11[504]

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh * CF

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498 Calculated using defaults: 1-((0.53/1.57) * 0.35) = 0.88.
499 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington). These results were judged to be equally applicable to Missouri.
500 These default system efficiencies are based on the applicable minimum federal standards. In 2006 and 2015, 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.
501 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.
502 Average (default) value of 35% electric space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.
503 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)), and it is based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington)). The estimate also assumes typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * $SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP). Results of the Iowa study are assumed to be applicable to Missouri.
504 The value is estimated at 1.11 (calculated as 1 + (0.91*(0.34 / 2.8)), which is based on assumption that 91% of homes have central cooling (based on 2009 Residential Energy Consumption Survey, see https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls').

Where:

ΔkWh = Electric energy savings, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001492529 for Lighting RES (Residential)

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes[505]

$$\Delta Therms = -((Watts_{\_Base} - Watts_{EE}) / 1{,}000 * ISR * Hours * HF * 0.03412) / \eta Heat * \%GasHeat$$

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 53%[506] for interior or unknown location
= 0% for exterior or unheated location
0.03412 =Converts kWh to therms
$\eta Heat_{Gas}$ = Efficiency of heating system
=71%[507]
%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[508]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE:

505 Negative value because this is an increase in heating consumption due to the efficient lighting.
506 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, Iowa. Results of the Iowa study were judged to be equally applicable to Missouri.
507 This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). See reference https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; ‘hc6.9.xls’. In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 15 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.
508 Average (default) value of 65% gas space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

3.5.3 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.

DEFINITION OF BASELINE 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.[509]

DEEMED MEASURE COST

Where possible, the actual cost should be used and compared to the baseline cost. If the incremental cost is unknown, assume $3.35.[510]

LOADSHAPE

Lighting RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{base}$ = Actual wattage if known, if unknown, assume 7W.[511]

$Watts_{EE}$ = Actual wattage of LED purchased / installed.

ISR = In Service Rate or the percentage of nightlights rebated that get installed

Leakage = Adjustment to account for the percentage of program bulbs that move out.
= Actual, or if unknown, 0% for Online Store and 4% for Upstream Lighting or 3.98% if unknown [512]

Hours = Average hours of use per year
= 4,380[513]

LKG = leakage rate (program bulbs installed outside Ameren Missouri's service area)
= Actual, or if unknown, assume 0%[514]

ISR = In Service Rate, the percentage of units rebated that are actually in service. Actual, or if unknown, assume:

[509] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2. and p.3.
[510] Average cost data provided in Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March 2018.
[511] Based on Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March 2018.
[512] Ameren Missouri Lighting Evaluation: PY2019. 3.98% is the weighted average for bulbs sold through the Online Store and Upstream Programs based on evaluation results and the distribution of bulbs in the PY19 program, https://www.efis.psc.mo.gov/Document/Display/15876, page 13 .
[513] Assumes nightlight is operating 12 hours per day, consistent with the 2016 Pennsylvania TRM.
[514] Assumed based on program delivery channels.

Program	Discounted In Service Rate (ISR)
Direct Install (MFLI) [515]	98.2%
Efficiency Kit (MF)[516]	100%
Low Income Kits	90%
Pay As You Save[517]	87%

WHFe = Waste Heat Factor for energy to account for the impact from reducing waste heat from efficient lighting on electric cooling and heating loads in residential homes.
= 0.99 if unknown[518]

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating, see calculation of heating penalty in that section).
= 1 - ((HF / ηHeat) * %ElecHeat).
= If unknown assume 0.88[519]

Where

HF = Heating Factor or percentage of light savings that must now be heated
= 53%[520] for interior location

$\eta Heat_{Electric}$ = Efficiency in COP of Heating equipment
= Actual - If not available, use:[521]

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[522]	N/A	N/A	1.28

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[523]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting

515 Ameren Missouri Community Savers Evaluation: PY2018, . https://www.efis.psc.mo.gov/Document/Display/36053, page 17.
516 Ameren Missouri Efficient Kits Impact and Process Evaluation: Program Year 2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 38.
517 Ameren Missouri Pay As You Save (PAYS®) Evaluation, https://www.efis.psc.mo.gov/Document/Display/17591, page 7.
518 Ameren Missouri PY2014 Evaluation, https://www.efis.psc.mo.gov/Document/Display/14194, page 45.
519 Calculated using defaults: 1-((0.53/1.57) * 0.35) = 0.88.
520 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington). These results were judged to be equally applicable to Missouri.
521 These default system efficiencies are based on the applicable minimum federal standards. In 2006 and 2015, 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.
522 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.
523 Average (default) value of 35% electric space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[524]
Building without cooling	1.0
Unknown	1.11[525]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001492529 for Lighting RES (Residential)

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes:[526]

$\Delta Therms = -((Watts\_{Base} - Watts_{EE}) / 1,000 * ISR * Hours * HF * 0.03412) / \eta Heat * \%GasHeat$

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 53%[527] for interior or unknown location
= 0% for exterior or unheated location

0.03412 =Converts kWh to therms

$\eta Heat_{Gas}$ = Efficiency of heating system
=71%[528]

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[529]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE:

524 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)), and it is based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington)). The estimate also assumes typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER^2) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP). Results of the Iowa study are assumed to be applicable to Missouri.

525 The value is estimated at 1.11 (calculated as 1 + (0.91*(0.34 / 2.8)), which is based on assumption that 91% of homes have central cooling (based on 2009 Residential Energy Consumption Survey, see https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls').

526 Negative value because this is an increase in heating consumption due to the efficient lighting.

527 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, Iowa. Results of the Iowa study were judged to be equally applicable to Missouri.

528 This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). See reference https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 15 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

529 Average (default) value of 65% gas space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

3.5.4 Ultra-Efficient LED Lighting

DESCRIPTION
This characterization provides savings assumptions for a variety of ultra-efficient LED screw-based lamp types including omnidirectional and specialty (globe, decorative and downlights) types. This characterization assumes that the LED lamp is installed in a residential location.

This measure was developed to be applicable to the following program types: TOS and KITS.

DEFINITION OF EFFICIENT EQUIPMENT
In order for this characterization to apply, new lamps must exceed efficiency specifications defined in the Standard-Efficiency LED Baseline Wattage Tables below. Consult the tables to find the maximum wattage that can be considered ultra-efficient for each bulb type.

Actual lamp wattages of the efficient equipment should be used to determine savings.

DEFINITION OF BASELINE EQUIPMENT
See "Standard-Efficiency LED Baseline Wattage" tables below for specific baseline wattages by lamp type and lumen output.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
According to the ENERGY STAR Qualified Products list (accessed 6/16/2020), the average rated life for Omnidirectional lamps is approximately 20,000 hours, 17,000 hours for decorative and 25,000 for directional lamps .

DEEMED MEASURE COST
The actual ultra-efficient LED lamp cost should be used. For incremental cost, assume a baseline cost according to the following table[530]:

Bulb Type	Standard LED Baseline Cost
Omnidirectional	$2.70
Directional	$5.18
Decorative and Globe	$3.40

LOADSHAPE
Lighting RES
Lighting BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (Watt_{Base} - Watt_{EE}) * ISR * (1 - LKG) * Hours * WHF / 1,000$$

Where:

$Watts_{Base}$ = Input wattage of the existing or baseline system. Reference the "Standard-Efficiency LED Baseline Wattage" table for default values.[531]

$Watts_{EE}$ = Actual wattage of LED purchased / installed must be used.

[530] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 366. 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. Given LED prices are expected to continue declining assumed costs should be reassessed on an annual basis and replaced with IL specific LED program information when available.
[531] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 367. See file 'LED Lamp Updates 2021-06-09.xlsx' for details on Guidehouse lamp wattage calculations based on equivalent baseline wattage and LED wattage of available ENERGY STAR product.

Standard-Efficiency LED Baseline Wattage Table: Omnidirectional

Minimum Lumens	Maximum Lumens	Standard LED Baseline Wattage (WattsBase)
120	399	4.0
400	749	6.6
750	899	9.6
900	1,399	13.1
1,400	1,999	16.0
2,000	2,999	21.8
3,000	3,299	28.9

Standard-Efficiency LED Baseline Wattage Table: Decorative Lamps

Bulb Type	Minimum Lumens	Maximum Lumens	Standard LED Baseline Wattage ($Watts_{Base}$)
Omni-Directional 3-Way	1,100	1,999	14.7
	2,000	2,700	22.6
Globe (medium and intermediate bases less than 750 lumens)	310	349	3.0
	350	499	4.7
	500	574	5.7
	575	649	6.5
	650	1,000	8.2
Globe (candelabra bases less than 1050 lumens)	310	349	3.5
	350	499	4.4
	500	574	5.5
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	310	499	4.3
	500	800	5.8
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	310	499	4.2
	500	650	5.5
Decorative (Shape ST)	310	499	6.5
	500	999	8.8
	1000	1500	10.0
Decorative (Shape S)	310	340	2.25

Standard-Efficiency LED Baseline Wattage Table: Directional Lamps

Bulb Type	Minimum Lumens	Maximum Lumens	Standard LED Baseline Wattage ($Watts_{Base}$)
Reflector lamp types with medium screw bases (PAR20, PAR30(S,L), PAR38, R40, etc.) w/ diameter >2.25"	400	649	7.0
	650	899	10.7
	900	1,049	13.9
	1,050	1,199	13.8
	1,200	1,499	15.9
	1,500	1,999	18.9
	2,000	3,299	27.3
Reflector lamp types with medium screw bases (PAR16, R14, R16, etc.) w/ diameter <2.25"	310	374	4.6
	375	600	6.4
BR30, BR40, or ER40	650	949	9.3
	950	1,099	12.7
	1,100	1,399	14.4
	1,400	1,600	16.6
	1,601	1,800	22.2
R20	450	524	6.0
	525	750	7.1
MR16	310	324	3.8
	325	369	4.8
	370	400	4.9

Standard-Efficiency LED Baseline Wattage Table: Additional EISA non-exempt bulb types

Bulb Type	Minimum Lumens	Maximum Lumens	Standard LED Baseline Wattage ($Watts_{Base}$)
Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	310	399	4.0
	400	749	6.6
	750	899	9.6
	900	1,399	13.1
	1,400	1,999	16.0

LKG = leakage rate (program bulbs installed outside Ameren Missouri's service area)
= Actual, or if unknown, assume 0%[532]

ISR = In Service Rate, the percentage of units rebated that are actually in service. Actual, or if unknown, assume:

[532] Assumed based on program delivery channels.

Program	Discounted In Service Rate (ISR)
Direct Install (MFLI) [533]	98.2%
Efficiency Kit (MF)[534]	100%
Low Income Kits	90%
Pay As You Save[535]	87%

Hours = Average hours of use per year for bulbs in residential homes. Custom, or if unknown assume 1,314[536] for exterior, or or if interior use table below.

Program	HOU Res
Residential	995.18[537]
Efficient Kits	995.18
Income Eligible RES	674.18[538]
MFMR	693.50[539]

WHFe = Waste Heat Factor for energy to account for the impact from reducing waste heat from efficient lighting on electric cooling and heating loads in residential homes.
= 0.99 if unknown[540]

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating, see calculation of heating penalty in that section).
= 1 - ((HF / ηHeat) * %ElecHeat).
= If unknown assume 0.88[541]

Where

HF = Heating Factor or percentage of light savings that must now be heated
= 53%[542] for interior or unknown location
= 0% for exterior or unheated location

$\eta Heat_{Electric}$ = Efficiency in COP of Heating equipment
= Actual - If not available, use:[543]

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[544]	N/A	N/A	1.28

533 Ameren Missouri Community Savers Evaluation: PY2018, . https://www.efis.psc.mo.gov/Document/Display/36053, page 17.
534 Ameren Missouri Efficient Kits Impact and Process Evaluation: Program Year 2018, https://www.efis.psc.mo.gov/Document/Display/15870, page 38.
535 Ameren Missouri Pay As You Save (PAYS®) Evaluation, https://www.efis.psc.mo.gov/Document/Display/17591, page 7.
536 Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. Average daily HOU for efficient bulbs is listed as 3.6 for outside bulbs and a weighted (by inventory) average of 1.99 for inside spaces. Unknown location is weighted average (by inventory) of all bulbs. See 'MO Lamp Hours.xlsx' for calculations.
537 Ameren Missouri Lighting Evaluation PY2018, https://www.efis.psc.mo.gov/Document/Display/15873, page 36.
538 Ameren Missouri Community Savers Evaluation PY2018 workpapers- Weighted Avg. HOU from ADM workpapers.
539 ADM 2017 Community Savers EM&V, https://www.efis.psc.mo.gov/Document/Display/28281, page 3-4.
540 Ameren Missouri PY2014 Evaluation, https://www.efis.psc.mo.gov/Document/Display/14194, page 45.
541 Calculated using defaults: 1-((0.53/1.57) * 0.35) = 0.88.
542 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington). These results were judged to be equally applicable to Missouri.
543 These default system efficiencies are based on the applicable minimum federal standards. In 2006 and 2015, 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.
544 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[545]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[546]
Building without cooling or exterior	1.0
Unknown	1.11[547]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001492529 for Lighting RES (Residential)

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes[548]

$\Delta Therms = -((Watts_{\_Base} - Watts_{EE}) / 1{,}000 * ISR * Hours * HF * 0.03412) / \eta Heat * \%GasHeat$

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 53%[549] for interior or unknown location
= 0% for exterior or unheated location

0.03412 =Converts kWh to therms

$\eta Heat_{Gas}$ = Efficiency of heating system
=71%[550]

%GasHeat = Percentage of homes with gas heat

545 Average (default) value of 35% electric space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

546 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)), and it is based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Iowa (Des Moines, Mason City, and Burlington)). The estimate also assumes typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm ($-0.02 * SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP). Results of the Iowa study are assumed to be applicable to Missouri.

547 The value is estimated at 1.11 (calculated as 1 + (0.91*(0.34 / 2.8)), which is based on assumption that 91% of homes have central cooling (based on 2009 Residential Energy Consumption Survey, see https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls').

548 Negative value because this is an increase in heating consumption due to the efficient lighting.

549 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, Iowa. Results of the Iowa study were judged to be equally applicable to Missouri.

550 This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). See reference https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 15 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[551]

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

MEASURE CODE:

[551] Average (default) value of 65% gas space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

3.6 Motors

3.6.1 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 pool 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%.[552] This measure is the characterization of the purchasing and installing of a new ENERGY STAR 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, and 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® variable speed residential pool pump for in-ground pools.

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:

Size Class	Baseline (Effective 7/19/2021)
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

For early replacement, the baseline 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 10 years.[553]

DEEMED MEASURE COST

For TOS and NC, the incremental cost is estimated $314 for a variable speed motor.[554]

For early replacement, the actual cost of the measure should be used; if actual is unknown, use $549. [555]

LOADSHAPE

Pool Spa RES

Algorithm

[552] U.S. DOE, 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. Report No. DOE/GO-102012-3534.
[553] The CEE Efficient Residential Swimming Pool Initiative (p. 18) indicates that the average motor life for pools in use year-round is 5-7 years. For pools in use for less than a third of the year, the expected lifetime is higher, so a 10-year assumption is selected. This assumption is consistent with DEER 2014 and the ENERGY STAR® Pool Pump Calculator, https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx assumptions.
[554] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 408. ENERGY STAR® Pool Pump Calculator, using the difference between the two speed pool pump and variable speed pool pump incremental costs.
[555] ENERGY STAR® Pool Pump Calculator, estimated cost for a variable speed pool pump, https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx

CALCULATION OF ENERGY SAVINGS

Electric Energy Savings[556]

For TOS and NC:

ΔkWh = (Gallons * Turnovers * (1/(WEF$_{base}$ – 1/WEF$_{ee}$) * Days) / 1,000 * ISR

For Early Replacement:

ΔkWh = (Gallons * Turnovers * (1/EF$_{exist}$ – 1/WEF$_{ee}$) * Days) / 1,000 * ISR

Where:

Gallons Capacity of the pool. Use actual, or if unknown assume 22,000.[557]

Turnovers = Desired number of pool water turnovers per day
= 2[558]

WEF$_{base}$ = Weighted Energy Factor of baseline pump (gal/Wh)
= Actual, or if unknown, assume 4.6[559]

WEF$_{ee}$ = Weighted Energy Factor of installed ENERGY STAR pump (gal/Wh)
= Actual, or if unknown, assume 6.31[560]

EF$_{exist}$ = Energy Factor of existing single speed pump (gal/Wh)
= Actual, or if unknown, assume 2.3[561]

Days = Days per year of operation
= 121.6[562]

1,000 = Conversion factor from Wh to kWh

ISR = In Service Rate
= Actual, or if unknown 100%[563] for the Efficiency Products Program.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0002354459

NATURAL GAS SAVINGS

N/A

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[556] Ibid. The methodology followed is consistent with the most recent version of the 2020 ENERGY STAR calculator (Pool_Pump_Calculator_2020.05.05_FINAL.xlsx), however this has not been updated to account for the new federal standard, https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.
[557] Ibid. Consistent with assumption in the 2020 ENERGY STAR calculator (Pool_Pump_Calculator_2020.05.05_FINAL.xlsx), https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.
[558] Ibid.
[559] Ibid. 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.
[560] Ibid. Based on applying the ENERGY STAR specifications to the average Curve-C rated hydraulic horsepower (hhp) from the ENERGY STAR Qualified Products List, accessed 3/31/2021.
[561] Ibid. Consistent with assumption in the 2020 ENERGY STAR calculator, assuming 1.5 HP pump (‘Pool_Pump_Calculator_2020.05.05_FINAL.xlsx’), https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.
[562] Ibid. Consistent with assumption in the 2020 ENERGY STAR calculator (‘Pool_Pump_Calculator_2020.05.05_FINAL.xlsx’), https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.
[563] Ibid. Consistent with assumption in the 2020 ENERGY STAR calculator, assuming 1.5 HP pump (‘Pool_Pump_Calculator_2020.05.05_FINAL.xlsx’), https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.

Water Impact Descriptions and Calculation
N/A

Deemed O&M Cost Adjustment Calculation
N/A

Measure Code:

3.7 Building Shell

3.7.1 Air Sealing

DESCRIPTION
Thermal shell air leaks are sealed through strategic use and location of air-tight materials. An estimate of savings is provided in two ways. It is highly recommended that leaks be detected and pre- and post-sealing leakage rates measured with the assistance of a blower-door by qualified/certified inspectors.[564] Where this occurs, an algorithm is provided to estimate the site-specific savings. Where test in/test out has not occurred, a prescriptive savings assumption is provided.

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
Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be assessed 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 affects the opportunity for cost-effective energy savings through air sealing.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 20 years.[565]

DEEMED MEASURE COST
The actual capital cost for this measure should be used.

LOADSHAPE
Building Shell RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
Methodology 1: Test In / Test Out Approach

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

If the home has central cooling, the electric energy saved in annual cooling due to the air sealing is:

$\Delta kWh_{cooling} = (((CFM50_{Pre} - CFM50_{Post}) / N_{cool}) * 60 * 24 * CDD * DUA * 0.018 * LM) / ((1{,}000 * \eta Cool))$

Where:

$CFM50_{Pre}$ = Infiltration at 50 Pascals as measured by blower door before air sealing
= Actual[566]

[564] Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.
[565] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 375. As recommended in Navigant ComEd Effective Useful Life Research Report, 'ComEd Effective Useful Life Research Report.pdf', May 2018.
[566] Because the pre- and post-sealing blower door test will occur on different days, there is a potential for the wind and temperature conditions on the two days to affect the readings. There are methodologies to account for these effects. For wind – first, if possible, avoid testing in high wind, place blower door on downwind side, take a pre-test baseline house pressure reading, adjust house pressure readings by subtracting the baseline reading, and use the time averaging feature on the digital gauge, etc. Corrections for air density due to temperature swings can be accounted for with air density correction factors. Refer to the Energy Conservatory Blower Door Manual for more information.

$CFM50_{Post}$ = 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 number of stories:[567]

Weather Basis (City based upon)	N_cool (by # of stories)			
	1	1.5	2	3
St Louis, MO	34.9	30.9	28.3	25.1

60 * 24 = Converts cubic feet per minute to cubic feet per day

CDD = Cooling Degree Days:[568]

Weather Basis (City based upon)	CDD 65
St Louis, MO	1,646

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)
= 0.75[569]

0.018 = Specific heat capacity of air (Btu/ft^3*°F)

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER2) of air conditioning equipment (kBtu/kWh)
= Actual (where it is possible to measure or reasonably estimate) - if unknown, assume the following: [570]

Age of Equipment	ηCool Estimate
Before 2006	9.5
2006 - 2014	12.4
Central AC After 1/1/2015	12.4
Heat Pump After 1/1/2015	13.3

LM = Latent multiplier to account for latent cooling demand: [571]

Weather Basis (City based upon)	LM
St Louis, MO	3.0

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the air sealing is:

$$\Delta kWh_{HeatingElectricGas} = (((CFM50_{Pre} - CFM50_{Post}) / N_{heat}) * 60 * 24 * HDD * 0.018) / (\eta Heat * 3{,}412)$$

Where:

N_{heat} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

[567] 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, https://eta-publications.lbl.gov/sites/default/files/exegesis_of_proposed_ashrae_std_119.pdf; 'exegesis_of_proposed_ashrae_std_119.pdf') 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-20151123.docx' and calculation worksheets.

[568] Based on climate normals data with a base temperature of 65°F.

[569] This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," 'Energy Center of WI Central AC in WI 2008.pdf', p. 31.

[570] 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. Note all ratings have been converted to SEER2 equivalents – since the new rating better reflects the actual efficiency of the units.

[571] The LM is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads. The values are derived from the methodology outlined in Infiltration Factor Calculation Methodology by Bruce Harley, Senior Manager, Applied Building Science, CLEAResult 11/18/2015 and is based upon an 8760 analysis of sensible and total heat loads using hourly climate data (see 'Infiltration Factor Calculations Methodology-20151123.docx').

= Based on building height:[572]

Weather Basis (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
St Louis, MO	24.0	21.3	19.5	17.3

HDD = Heating Degree Days

Weather Basis (City based upon)	HDD 65
St Louis, MO	4,486

ηHeat = Efficiency of heating system
= Actual - if not available refer to default table below:[573]

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[574]	N/A	N/A	1.28

3412 = Converts Btu to kWh

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to air sealing since the furnace fans will run less.

$\Delta kWh_{HeatingGas}$ = ΔTherms * F_e * 29.3

Where:

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[575]

29.3 = kWh per therm

[572] 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, https://eta-publications.lbl.gov/sites/default/files/exegesis_of_proposed_ashrae_std_119.pdf) 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" and calculation worksheets.

[573] 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.

[574] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.

[575] 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 'Furnace Fan Analysis.xlsx' for reference.

<u>Methodology 2: Prescriptive Infiltration Reduction Measures</u>[576]

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

$\Delta kWh = (\Delta kWh_{cooling} + \Delta kWh_{heating})$

If the home has central cooling, the electric energy saved in annual cooling due to the air sealing is:

$$\Delta kWh_{cooling} = (\Delta kWh_{cool\_gasket} * n_{gasket} + \Delta kWh_{cool\_sweep} * n_{sweep} + \Delta kWh_{cool\_sealing} * lf_{sealing} + \Delta kWh_{cool\_wx} * lf_{wx}) * ADJ_{RxAirsealing}$$

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the air sealing is:

$$\Delta kWh_{heatingelectric} = (\Delta kWh_{heat\_gasket} * n_{gasket} + \Delta kWh_{heat\_sweep} * n_{sweep} + \Delta kWh_{heat\_sealing} * lf_{sealing} + \Delta kWh_{heat\_wx} * lf_{wx}) * \%ElectricHeat * ADJ_{RxAirsealing}$$

Where:

n_{gasket} = Number of gaskets installed

n_{sweep} = Number of sweeps installed

$lf_{sealing}$ = Linear feet of caulking, sealing, or polyethylene tape

lf_{wx} = Linear feet of window weatherstripping or door weatherstripping

Measure	Savings Variable Names	ΔkWhheat/Unit			ΔkWhcool/Unit	
		Electric Resistance	Heat Pump	Electric Heat Type Unknown[577]	With Cooling	Unknown Cooling
Outlet Gasket	ΔkWh_{cool_gasket} ΔkWh_{heat_gasket}	7.19	3.59	5.9	1.63	1.07
Door Sweep	ΔkWh_{cool_sweep} ΔkWh_{heat_sweep}	138.2	69.1	114.0	6.39	4.22
Caulking/Sealing/Polyethylene Tape	$\Delta kWh_{cool\_sealing}$ $\Delta kWh_{heat\_sealing}$	7.91	3.95	6.5	0.17	0.11
Window or door weatherstripping	ΔkWh_{cool_wx} ΔkWh_{heat_wx}	9.19	4.59	7.6	0.16	0.11

%ElectricHeat = Percentage of homes with electric heat

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[578]

[576] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 382. 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 applicable weather data. Cooling savings derived using savings assumptions pulled from ASHRAE, 2001 AHSRAE Handbook – Fundamentals, Chapter 26, Table 1. Effective Air Leakage Areas (Low-Rise Residential Applications Only). See ‘Air Sealing Prescriptive Savings 07.06.2024.xlsx’ for more information.

[577] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; ‘hc6.9.xls’.

[578] Average (default) value of 35% electric space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[579]
= 80%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0004660805[580]

NATURAL GAS SAVINGS
<u>Methodology 1: Test In / Test Out Approach</u>
If natural gas heating:

$\Delta Therms = (((CFM50_{Pre} - CFM50_{Post})/ N_{heat}) * 60 * 24 * HDD * 0.018) / (\eta Heat * 100,000)$

Where:
N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions
= Based on building height:[581]

Weather Basis (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
St Louis, MO	24.0	21.3	19.5	17.3

HDD = Heating Degree Days

Weather Basis (City based upon)	HDD 65
St Louis, MO	4,486

$\eta Heat$ = Efficiency of heating system
= Equipment efficiency * distribution efficiency
= Actual[582] - if not available, use 71%[583]

Other factors as defined above

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579 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, p. 384.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.
580 Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors"for residential HVAC end-use.
581 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, https://eta-publications.lbl.gov/sites/default/files/exegesis_of_proposed_ashrae_std_119.pdf) 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" and calculation worksheets.
582 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 (https://www.bpi.org/__cms/docs/Guidance%20on%20Estimating%20Distribution%20Efficiency.pdf; 'Guidance on Estimating Distribution Efficiency.pdf') or by performing duct blaster testing.
583 This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 16 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

Methodology 2: Prescriptive Infiltration Reduction Measures[584]

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

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the air sealing is:

$\Delta Therms = (\Delta Therms_{gasket} * n_{gasket} + \Delta Therms_{sweep} * n_{sweep} + \Delta Therms_{sealing} * lf_{sealing} + \Delta Therms_{wx} * lf_{wx}) * (1 - \%ElectricHeat) * ADJ_{RxAirsealing}$

Where:

Measure	Savings Variable Names	ΔTherms/Unit
Outlet Gasket	$\Delta Therms_{gasket}$	0.34
Door Sweep	$\Delta Therms_{sweep}$	6.46
Caulking/Sealing/Polyethylene Tape	$\Delta Therms_{sealing}$	0.37
Window or door weatherstripping	$\Delta Therms_{wx}$	0.43

Other factors as defined above

Water Impact Descriptions and Calculation
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[584] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 382. 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 applicable weather data. Cooling savings derived using savings assumptions pulled from ASHRAE, 2001 AHSRAE Handbook – Fundamentals, Chapter 26, Table 1. Effective Air Leakage Areas (Low-Rise Residential Applications Only). See 'Air Sealing Prescriptive Savings 07.06.2024.xlsx' for more information.

3.7.2 Ceiling Insulation

DESCRIPTION

This measure describes savings from adding insulation to the attic/ceiling. 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 type: RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 30 years.[585]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Building Shell RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

If the home has central cooling, the electric energy saved in annual cooling due to the ceiling insulation is:

$\Delta kWh_{cooling} = ((1/R_{Old} - 1/R_{Attic}) * A_{attic} * (1 – FramingFactor_{Attic}) * CDD * 24 * DUA * ADJ_{AtticCool}) / (1{,}000 * \eta Cool)$

Where

R_{Attic} = R-value of new attic assembly including all layers between inside air and outside air (ft^2.°F.h/Btu)

R_{Old} = R-value value of existing assembly and any existing insulation (Minimum of R-5 for uninsulated assemblies[586])

A_{Attic} = Total area of insulated ceiling/attic (ft^2)

$FramingFactor_{Attic}$ = Adjustment to account for area of framing = 7%[587]

CDD = Cooling Degree Days:[588]

[585] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 421. As recommended in Guidehouse 'EMV Group A, Deliverable 16 EUL Research – Residential Insulation' (see https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf; 'CPUC Insulation EUL Draft Report 06292021.pdf'), prepared for California Public Utilities Commission, June 2021.

[586] 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).

[587] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," '2001 - ASHRAE - Characterization of Framing Factors.pdf', Table 7.1

[588] Based on climate normals data with a base temp of 65°F.

Weather Basis (City based upon)	CDD 65
St Louis, MO	1,646

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)
= 0.75[589]

1000 = Converts Btu to kBtu

ηCool = Seasonal energy efficiency ratio of cooling system (kBtu/kWh)
= Actual (where it is possible to measure or reasonably estimate) – if unknown, assume the following: [590]

Age of Equipment	ηCool Estimate
Before 2006	9.5
2006 - 2014	12.4
Central AC After 1/1/2015	12.4
Heat Pump After 1/1/2015	13.3
Unknown	12.4

$ADJ_{AtticCool}$ = Adjustment to cooling savings to account for to account for inaccuracies in engineering algorithms.
= 114%[591]

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the ceiling insulation is:

$\Delta kWh_{HeatingElectric}$ = $((1/R_{Old} - 1/R_{Attic}) * A_{attic} * (1 – FramingFactor_{Attic}) * HDD * 24 * ADJ_{AtticHeat}) / (3,412 * \eta Heat)$

Where:

HDD = Heating Degree Days

Weather Basis (City based upon)	HDD 65
St Louis, MO	4,486

ηHeat = Efficiency of heating system
= Actual - if not available, refer to default table below:[592]

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[593]	N/A	N/A	1.28

[589] This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," 'Energy Center of WI Central AC in WI 2008.pdf', p. 31.

[590] 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. Note all ratings have been converted to SEER2 equivalents – since the new rating better reflects the actual efficiency of the units.

[591] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 424. As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). ComEd and Nicor Gas Air Sealing and Insulation Research Report. Presented to Commonwealth Edison Company and Nicor Gas Company. 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. Applied the percent change of NCEI Annual Normals CDD65 from 30 yr data set (1981-2010) to more recent 15 yr data (2006-2020) for all cooling-related adjustment values.

[592] These default system efficiencies are based on the applicable minimum federal standards. In 2006 the federal standard for heat pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

[593] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.

3,412 = Converts Btu to kWh
$ADJ_{AtticHeat}$ = Adjustment to heating savings to account for to account for inaccuracies in engineering algorithms.
= 63%[594]

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the ceiling insulation is:

$\Delta kWh_{HeatingElectricGas}$ = $\Delta Therms * F_e * 29.3$

Where:
F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[595]
29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0. 0004660805[596]

NATURAL GAS SAVINGS

Methodology 1:

ΔTherms (if Natural Gas heating)

$$= ((1/R_{Old} - 1/R_{Attic}) * A_{attic} * (1 – FramingFactor_{Attic}) * HDD * 24 * ADJ_{AtticHeat}) / (100{,}000 * \eta Heat)$$

Where:
HDD = Heating Degree Days

Weather Basis (City based upon)	HDD 65
St Louis, MO	4,486

ηHeat = Efficiency of heating system
= Equipment efficiency * distribution efficiency

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594 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 425. As demonstrated in air sealing and insulation research by Navigant, Navigant (2018). ComEd and Nicor Gas Air Sealing and Insulation Research Report. Presented to Commonwealth Edison Company and Nicor Gas Company. Applied the percent change of NCEI Annual Normals HDD60 from 30 yr data set (1981-2010) to more recent 15 yr data (2006-2020) for all heating-related adjustment values.
595 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 'Furnace Fan Analysis.xlsx' for reference.
596 Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for residential HVAC end-use.

= Actual.[597] If unknown, assume 71%.[598]

100,000 = Converts Btu to therms

Other factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[597] Ideally, the system efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The distribution efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute (https://www.bpi.org/__cms/docs/Guidance%20on%20Estimating%20Distribution%20Efficiency.pdf; 'Guidance on Estimating Distribution Efficiency.pdf') or by performing duct blaster testing.

[598] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 16 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

3.7.3 Duct Insulation

DESCRIPTION

This measure describes evaluating the savings associated with performing duct insulation on the distribution system of homes with central cooling and/or a ducted heating system. While insulating ducts in conditioned space can help with control and comfort, energy savings are largely limited to insulating ducts in unconditioned space where the heat loss is to outside the thermal envelope. Therefore, for this measure to be applicable, at least 30% of ducts should be within unconditioned space (e.g., attic with floor insulation, vented crawlspace, unheated garages. Basements should be considered conditioned space).

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

The efficient condition is insulated duct work throughout the unconditioned space in the home.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is existing duct work with at least 30% of the ducts within the unconditioned space in the home.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[599]

DEEMED MEASURE COST

The actual duct insulation measure cost should be used.

LOADSHAPE

HVAC RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the home and energy saved when heating the home.

$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$

If the home has central cooling, the electric energy saved in annual cooling due to the added insulation is:

$\Delta kWh_{Cooling} = (1/R_{existing} - 1/R_{new}) * Area * EFLH_{cool} * \Delta T_{AVG,cooling}) / (1,000 * SEER2)$

Where:

$R_{existing}$ = Duct heat loss coefficient with existing insulation ((hr-^{0}F-ft^2)/Btu)
= Actual

R_{new} = Duct heat loss coefficient with new insulation (hr-^{0}F-ft^2)/Btu)
= Actual

Area = Area of the duct surface exposed to the unconditioned space that has been insulated (ft^2)

$EFLH_{cool}$ = Equivalent Full Load Cooling Hours:

[599] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, https://energizect.com/sites/default/files/documents/Measure%20Life%20Report%202007.pdf; 'Measure Life Report 2007.pdf', page 1-3.

Weather Basis (Ameren Missouri Average)	EFLHcool (Hours)
SF or MF	869[600]
MFc (comprehensive envelope)	632[601]

$\Delta T_{AVG,cooling}$ = Average temperature difference (^{0}F) during cooling season between outdoor air temperature and assumed 60^{0}F duct supply air temperature[602]

Weather Basis (City based upon)	$OA_{AVG,cooling}$ [°F][603]	$\Delta T_{AVG,cooling}$ [°F]
St Louis, MO	80.8	20.8

1,000 = Converts Btu to kBtu

SEER2 = Seasonal Energy Efficiency Ratio of Air Conditioning equipment (kBtu/kWh)

= Actual - If not available, assume the following: [604]

Age of Equipment	ηCool Estimate
Before 2006	9.5
2006 - 2014	12.4
Central AC After 1/1/2015	12.4
Heat Pump After 1/1/2015	13.3

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$\Delta kWh_{HeatingElectric}$ = $(1/R_{existing} - 1/R_{new}) * Area * EFLH_{heat} * \Delta T_{AVG,heating}) / (3{,}412 * COP)$

Where:

EFLHheat = Equivalent Full Load Heating Hours:[605]

Weather Basis (Ameren Missouri Average)	EFLHheat (Hours)
SF or MF	1,496
MFc (comprehensive envelope)	509

$\Delta T_{AVG,heating}$ = Average temperature difference (^{0}F) during heating season between outdoor air temperature and assumed 115ºF duct supply temperature[606]

Weather Basis (City based upon)	$OA_{AVG,heating}$ [°F][607]	$\Delta T_{AVG,heating}$ [°F]
St Louis, MO	43.2	71.8

3,412 = Converts Btu to kWh

COP = Efficiency in COP of heating equipment

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600 PY2019 Residential Evaluation Report, https://www.efis.psc.mo.gov/Document/Display/15876, page 30.

601 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.

602 Leaving coil air temperatures are typically about 55ºF. Therefore, 60ºF is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

603 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 https://doe2.com/Download/Weather/TMY3/. Heating season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

604 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. Note all ratings have been converted to SEER2 equivalents – since the new rating better reflects the actual efficiency of the units.

605 Evaluation - Opinion Dynamics review PY2019. The recommended values are constructed based on weather conditions (heating degree days and cooling degree days) in select Missouri cities (St. Louis, Cape Girardeau, Kansas City), weighted by partial year 2019 installations.

606 Forced air supply temperatures are typically 130ºF. 115ºF is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

607 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 https://doe2.com/Download/Weather/TMY3/. Heating season defined as September 17 through April 13, cooling season defined as May 20 through August 15. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

= Actual - if not available, use:

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[608]	N/A	N/A	1.28

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$\Delta kWh_{HeatingGas}$ = ΔTherms * Fe * 29.3

Where:

ΔTherms = Therm savings as calculated in Natural Gas Savings

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[609]

29.3 = Converts therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh_{Cooling} * CF$

Where:

$\Delta kWh_{Cooling}$ = Electric energy savings for cooling, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0004660805

NATURAL GAS SAVINGS

If home uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$\Delta Therms = (1/R_{existing} - 1/R_{new}) * Area * EFLH_{heat} * \Delta T_{AVG,heating}) / (100{,}000 * \eta HeatGas)$

Where: ηHeatGas equals 71%[610] and all factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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[608] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.

[609] 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.

[610] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 16 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

MEASURE CODE:

3.7.4 Floor Insulation

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 "Foundation Sidewall 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 type: RF.

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

DEFINITION OF EFFICIENT EQUIPMENT
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 30 years.[611]

DEEMED MEASURE COST
The actual installed cost for this measure should be used in screening.

LOADSHAPE
Building Shell RES

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, the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings:

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

If the home has central cooling, the electric energy saved in annual cooling due to the floor insulation is:

$\Delta kWh\_cooling = ((1/R\_{Old} - 1/(R_{Added} + R_{Old})) * Area * (1 – FramingFactor_{Floor}) * CDD * 24 * DUA * ADJ_{FloorCool}) / (1,000 * \eta Cool)$

Where:

R_{Old} = R-value value of floor before insulation, assuming 3/4" plywood subfloor and carpet with pad
= Actual. If unknown, assume 3.53[612]

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

Area = Total floor area to be insulated

[611] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 402. As recommended in Guidehouse 'EMV Group A, Deliverable 16 EUL Research – Residential Insulation' (see https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf; 'CPUC Insulation EUL Draft Report 06292021.pdf'), prepared for California Public Utilities Commission, June 2021.

[612] Ibid., page 404. 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.

$FramingFactor_{Floor}$ = Adjustment to account for area of framing
= 12%[613]
24 = Converts hours to days
CDD = Cooling Degree Days

Weather Basis (City based upon)	Unconditioned Space
	CDD 75 [614]
St Louis, MO	762

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions call for it).
= 0.75[615]
1000 = Converts Btu to kBtu
ηCool = Seasonal energy efficiency ratio of cooling system (kBtu/kWh)
= Actual (where it is possible to measure or reasonably estimate). If unknown, assume the following: [616]

Age of Equipment	ηCool Estimate
Before 2006	9.5
2006 - 2014	12.4
Central AC After 1/1/2015	12.4
Heat Pump After 1/1/2015	13.3

$ADJ_{FloorCool}$ = Adjustment to cooling savings to account for to account for inaccuracies in engineering algorithms.
= 75%[617]

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the floor insulation is:

$\Delta kWh_{HeatingElectric}$ = ((1/R_ $_{Old}$ - 1/(R_{Added} + R_{Old})) * Area * (1 – $FramingFactor_{Floor}$) * HDD * 24 * $ADJ_{FloorHeat}$) / (3,412 * ηHeat)

Where:
HDD = Heating Degree Days:

Weather Basis Zone (City based upon)	Unconditioned Space
	HDD 50 [618]
St Louis, MO	1,911

ηHeat = Efficiency of heating system
= Actual -- if not available, refer to default table below:

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613 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," '2001 - ASHRAE - Characterization of Framing Factors.pdf', Table 7.1.
614 The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. Five-year average cooling degree days with 75F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72F.
615 This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," 'Energy Center of WI Central AC in WI 2008.pdf', p. 31.
616 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. Note all ratings have been converted to SEER2 equivalents – since the new rating better reflects the actual efficiency of the units.
617 Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 405. As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis" ('Memo on Ameren HPwES Billing Analysis FINAL 2015-03-06.pdf'), dated February 20, 2015. Applied the percent change of NCEI Annual Normals CDD65 from 30 yr data set (1981-2010) to more recent 15 yr data (2006-2020) for all cooling-related adjustment values.
618 The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

System Type		Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)		Before 2006	5.8	1.44
		After 2006 - 2014	6.5	1.62
		2015 on	7.0	1.74
Resistance		N/A	N/A	1.00
Unknown[619]		N/A	N/A	1.28

$ADJ_{FloorHeat}$ = Adjustment to heating savings to account for to account for inaccuracies in engineering algorithms.
= 63%[620]

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the floor insulation is:

$\Delta kWh_{HeatingElectricGas}$ = ΔTherms * F_e * 29.3

Where:

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[621]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh * CF

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0. 0004660805[622]

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= ((1/R\_{Old} - 1/(R_{Added} + R_{Old})) * Area * (1 – FramingFactor_{Floor}) * HDD * 24 * ADJ_{FloorHeat}) / (100,000 * \eta Heat)$$

Where

ηHeat = Efficiency of heating system
= Equipment efficiency * distribution efficiency

[619] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.

[620] Illinois TRM Version 12.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010124_v12.0_Vol_3_Res_09222023_FINAL_clean.pdf, page 406. As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis" ('Memo on Ameren HPwES Billing Analysis FINAL 2015-03-06.pdf'), dated February 20, 2015. Applied the percent change of NCEI Annual Normals HDD60 from 30 yr data set (1981-2010) to more recent 15 yr data (2006-2020) for all heating-related adjustment values.

[621] 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.

[622] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for residential building shell end-use.

	= Actual[623] - If not available, use 71%[624]
100,000	= Converts Btu to therms
	Other factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[623] 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 (https://www.bpi.org/__cms/docs/Guidance%20on%20Estimating%20Distribution%20Efficiency.pdf; 'Guidance on Estimating Distribution Efficiency.pdf') or by performing duct blaster testing.
[624] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 16 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

3.7.5 Storm Windows

DESCRIPTION

Storm windows installed on either the interior or exterior of existing window assemblies can reduce both heating and cooling loads by reducing infiltration and solar heat gain and improving insulation properties. Glass options for storm windows can include traditional clear glazing as well as low-emissivity (Low-E) glazing. Low-E glass is formed by adding an ultra-thin layer of metal to clear glass. The metallic-oxide (pyrolytic) coating is applied when the glass is in its molten state, and the coating becomes a permanent and extremely durable part of the glass. This coating is also known as "hard-coat" Low-E. Low-E glass is designed to redirect heat back towards the source, effectively providing higher insulating properties and lower solar heat gain as compared to traditional clear glass. This characterization captures the savings associated with installing storm windows to an existing window assembly (retrofit).

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

An interior or exterior storm window installed according to manufacturer specifications.

DEFINITION OF BASELINE EQUIPMENT

The existing window assembly.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

20 years[625]

DEEMED MEASURE COST

The actual capital cost for this measure should be used when available and include both material and labor costs. If unavailable, the cost for a low-e storm window can be assumed as $7.85/ft^2$ of window area (material cost) plus $30 per window for installation expenses.[625] For clear glazing, cost can be assumed as $6.72/ft^2$ of window area (material cost) plus $30 per window for installation expenses.[626]

LOADSHAPE

Building Shell RES

Algorithm

CALCULATION OF SAVINGS

The following reference tables show savings factors (kBtu/ft^2) for both heating and cooling loads.[627] They are used with savings equations listed in the electric energy and gas savings sections to produce savings estimates. If storm windows are left installed year-round, both heating and cooling savings may be claimed. If they are installed seasonally, only heating savings should be claimed. Savings are dependent on location, storm window location (interior or exterior), glazing type (clear or Low-E) and existing window assembly type.

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[625] Task ET-WIN-PNNL-FY13-01_5.3: Database of Low-E Storm Window Energy Performance across U.S. Climate Zones. KA Cort and TD Culp, 'Culp ET Task 5_3_PNNL-22865_Final2.pdf', September 2013. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory. PNNL-22864.

[626] A comparison of Low-E to clear glazed storm windows available at large national retail outlets showed the average incremental cost for Low-E glazing to be $1.13/ft^2. Installation costs are identical.

[627] Missouri TRM 2017, https://dnr.mo.gov/document-search/missouri-technical-reference-manual-2017-volume-3-residential-measures, p. 193. Savings factors are based on simulation results, St. Louis, MO, weather basis.

Heating Savings Factors ($SavingsFactor_{heat}$):

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	47.7	13.3	48.5	12.3
	CLEAR INTERIOR	49.8	17.9	49.0	14.2
	LOW-E EXTERIOR	51.5	13.3	53.2	19.3
	LOW-E INTERIOR	57.7	20.3	55.9	17.5

Cooling Savings Factors ($SavingsFactor_{cool}$):

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	23.0	10.5	22.5	9.6
	CLEAR INTERIOR	23.9	10.7	24.4	9.8
	LOW-E EXTERIOR	29.5	15.4	29.3	9.3
	LOW-E INTERIOR	28.8	14.2	29.0	13.4

ELECTRIC ENERGY SAVINGS

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

Where:

$\Delta kWh_{cooling}$ = If storm windows are left installed during the cooling season and the home has central cooling, the reduction in annual cooling requirement due to air sealing

= $\Sigma SavingsFactor_{cool} * A / \eta Cool$

Σ_{cool} = Savings factor for cooling, as tabulated above.

A = Area (square footage) of storm windows installed.

ηCool = Efficiency (SEER2) of Air Conditioning equipment (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate) - If unknown, assume the following: [628]

Age of Equipment	ηCool Estimate
Before 2006	9.5
2006 - 2014	12.4
Central AC After 1/1/2015	12.4
Heat Pump After 1/1/2015	13.3

$\Delta kWh_{heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

= $\Sigma SavingsFactor_{heat} * A / \eta Heat * 3.412$

Σ_{heat} = Savings factor for heating, as tabulated above.

[628] 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. Note all ratings have been converted to SEER2 equivalents – since the new rating better reflects the actual efficiency of the units.

ηHeat = Efficiency of heating system
= Actual - If not available refer to default table below:

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (COP Estimate) = (HSPF2/3.413)*0.85
Heat Pump (if age unknown assume 2006-2014)	Before 2006	5.8	1.44
	After 2006 - 2014	6.5	1.62
	2015 on	7.0	1.74
Resistance	N/A	N/A	1.00
Unknown[629]	N/A	N/A	1.28

3.412 = Converts kBtu to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh_{Cooling} * CF$

Where:

$\Delta kWh_{Cooling}$ = Electric energy savings for cooling, calculated above
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0. 0004660805[630]

NATURAL GAS SAVINGS
If Natural Gas heating:

$\Delta Therms = \Sigma_{heat} * A / \eta Heat * 100$

Where:
ηHeat = Efficiency of heating system
= Equipment efficiency * distribution efficiency
= Actual[631] - If not available, use 71%[632]
100 = Converts kBtu to therms
Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

[629] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, https://www.eia.gov/consumption/residential/data/2009/hc/hc6.9.xls; 'hc6.9.xls'. 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.
[630] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for residential building shell end-use.
[631] 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 (https://www.bpi.org/__cms/docs/Guidance%20on%20Estimating%20Distribution%20Efficiency.pdf; 'Guidance on Estimating Distribution Efficiency.pdf') or by performing duct blaster testing.
[632] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri 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, so units purchased 16 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: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

MEASURE CODE:

3.7.6 Cool Roof

DESCRIPTION
Cool (high albedo) roofing materials reduce the overall heat load on a home by reflecting more of the incident solar radiation, thus decreasing the total heat energy absorbed into the building system. This reduction in heat load provides space cooling energy savings during the cooling season but can increase heating energy use during the winter. Therefore, cool roofs are most beneficial in warmer climates and may not be recommended for homes where the primary heat source is electric resistance.

This measure is only applicable to existing buildings constructed before 2016 that have not undergone roof improvements since 2016.

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 condition is cool (high albedo) roofing material. Although, the ENERGY STAR cool roof rating was discontinued, the minimum thresholds are listed for the required minimum solar reflectance and thermal emittance by the roof slope. The *Cool Roof Rating Council* provides ratings at https://coolroofs.org/directory/roof.

Roof Slope/Pitch	Solar Reflectance 1 Year	Solar Reflectance 3 Year	Thermal Emittance
Low slope/≤2:12 pitch	≥0.65	≥0.5	≥0.75
Steep slope/>2:12 pitch	≥0.25	≥0.15	≥0.75

DEFINITION OF BASELINE EQUIPMENT
The baseline condition is assumed to be a conventional asphalt shingle roof of albedo 0.142. For other existing roofing materials, the reflectance and emittance values can be sourced, with savings determined by the calculators built by the Oak Ridge National Laboratory for low slope[633] and steep slope[634] roofs.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 15 years.[635]

DEEMED MEASURE COST
The actual implementation cost for applying cool (high albedo) roof should be used.

LOADSHAPE
Building Shell RES

Algorithm

CALCULATION OF SAVINGS
Mid-America Regional Council (MARC), in partnership with Lawrence Berkeley National Laboratory (LBNL), commissioned Leidos to study building energy consumption. The study area was a nine-county region identified by MARC. A whole-building energy modeling tool was used to evaluate urban heat island (UHI) countermeasure strategies for several common residential building categories based on models developed by the U.S. Department of Energy (DOE). Residential buildings were adapted to the Kansas City region to model changes in building energy consumption.

The LBNL study modeled four vintages of residential single and multi-family buildings. They are categorized as,

[633] Oak Ridge National Laboratory, Low slop roof savings calculator, https://web.ornl.gov/sci/buildings/tools/cool-roof/
[634] Oak Ridge National Laboratory, Steep slope roof savings calculator, https://web.ornl.gov/sci/buildings/tools/SteepSlopeCalc/
[635] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/component/users/?view=login.

Vintage Group	Year of construction	Adjusted Distribution %
Pre-1980	up to 1979	59%
Post-1980	1980-1999	25%
IECC 2006	2000-2009	13%
IECC 2012	2010-2015	3%

ELECTRIC ENERGY SAVINGS

ΔkWh = Cooling Savings * SF / 1,000 * HeatingFactor

Where:

Cooling Savings = Dependent on home vintage and type (single family vs. multi-family): [636]

Vintage Group	kWh/1000 ft^2 Cooling Savings	
	Single Family	Multi-Family
Up to 1979	136.0	114.0
1980-1999	73.9	58.1
2000-2009	33.3	24.9
2010-2015	23.9	19.5

SF = Area of cool roof in square feet.

HeatingFactor =0[637] for Electric Resistance heating
=0.42[638] for Heat Pump heating
=1.0 for non-electric heating

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh * CF

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0. 0004660805[639]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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[636] The annual site energy savings by roof area for each of the residential prototypes from the installation of cool roofs instead of conventional roofs (scenario RR-2 in Leidos 2015b). Leidos. (2015b) Energy savings of high albedo roofs for the Kansas City Area. Leidos report commissioned by the Mid-America Regional Council. September 2015.

[637] Average reduction in savings due to electric heat, calculated with the ORNL Cool Roof calculator. Local file: "Residential Cool Roofs.xlsx"

[638] Ibid.

[639] Based on Ameren Missouri TRM Volume 1 - Appendix G: "Table 1 – Residential End Use Category Monthly Shapes and Coincident Peak Factors" for residential building shell end-use.

3.8 Residential Demand Response

3.9.1 Residential Demand Response Analysis Approach

DESCRIPTION

For residential demand response measures, the energy and demand impacts of residential demand response events will be analyzed using AMI interval data. The baseline for measuring impacts will be established by creating a control group of non-participant customers with similar energy usage patterns and weather conditions. This control group will be used to estimate what energy usage would have been in the absence of a demand response event.

The analysis will include weather normalization to ensure that the baseline reflects the weather conditions experienced during the event. Demand reduction will be calculated as the difference between the weather-normalized baseline and the actual energy use during the event period.

If AMI data is not available for all participants, results will be extrapolated to represent the broader participant population.

3.9.2 Demand Response Advanced Thermostat

DESCRIPTION

This measure characterizes the demand savings achieved by managing customer energy loads during peak periods through a residential demand response (DR) program. It also characterizes the energy savings resulting from load shaping strategies employed during non-peak hours to reduce overall usage. Savings impacts will be evaluated using ex-post analysis, primarily leveraging AMI interval data to compare energy consumption with and without program intervention.

The evaluation approach includes establishing a control group through propensity score matching with non-participant customers who have similar energy usage patterns and weather conditions. The analysis involves weather normalization to ensure accurate baseline estimations. The savings impacts will be determined by comparing the treatment group's energy use during DR events to the weather-normalized baseline.

As advanced thermostats evolve, some models include embedded optimization routines that can independently achieve energy savings. The program, however, will only attribute savings to the incremental impact of "program-driven optimization"—those savings achieved through the program's influence in activating or enhancing the thermostat's optimization features. Energy savings that result from default or non-program-driven optimization will not be attributed to the program.

Due to the custom nature of the evaluation, ex-post demand and energy savings calculations will be based on the specific conditions and data available each year, with previous year results informing program planning and goal setting for subsequent cycles.

This measure was developed to be applicable to the following program type: DR.

DEFINITION OF EFFICIENT CASE

The efficient case is a customer who participates in the DR program, where the thermostat is under the control of the program. In this case, energy consumption is directly influenced by program-driven strategies, including load shaping during non-peak hours and demand reduction during peak periods.

DEFINITION OF BASELINE CASE

The baseline case is a customer who is not participating in the DR program and whose thermostat operates independently of program-driven strategies. The baseline for measuring impacts will be established by creating a control group of non-participant customers with similar energy usage patterns and weather conditions. This control group will be used to estimate what energy usage would have been in the absence of a demand response event. The analysis will include weather normalization to ensure that the baseline reflects the weather conditions experienced during the event. If AMI data is not available for all participants, results will be extrapolated to represent the broader participant population.

DEEMED LIFETIME OF PROGRAM SAVINGS

The expected measure life is assumed to be 1 year.

DEEMED MEASURE COST

It is assumed that program-controlled changes in residential settings are accomplished without homeowner investment in new equipment. Therefore, without evidence to the contrary, measure costs in such residential programs focused on program controlled changes in customer behavior may be defined as $0.

LOADSHAPE

HVAC RES (for optimization routines that save energy during the cooling and heating seasons)
Cooling RES (for optimization routines that save energy only during the cooling season)
Heating RES (for optimization routines that save energy only during the heating season)

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

3.9.3 Demand Response Water Heater Switch

DESCRIPTION

This measure characterizes the demand savings achieved by controlling residential water heater loads during peak periods through a demand response (DR) program. Savings impacts will be evaluated using ex-post analysis, primarily leveraging AMI interval data to compare energy consumption during peak periods with and without program intervention.

The evaluation approach includes establishing a control group through propensity score matching with non-participant customers who have similar energy usage patterns and weather conditions. The analysis involves weather normalization to ensure accurate baseline estimations. The demand savings impacts will be determined by comparing the treatment group's energy use during DR events to the weather-normalized baseline.

Due to the custom nature of the evaluation, ex-post demand savings calculations will be based on the specific conditions and data available each year, with previous year results informing program planning and goal setting for subsequent cycles.

This measure was developed to be applicable to the following program type: DR.

DEFINITION OF EFFICIENT CASE

The efficient case is a customer who participates in the DR program, where the water heater is under the control of the program. In this case, demand reduction is directly influenced by program-driven strategies during peak periods.

DEFINITION OF BASELINE CASE

The baseline case is a customer who is not participating in the DR program and whose water heater operates independently of program-driven strategies. The baseline for measuring impacts will be established by creating a control group of non-participant customers with similar energy usage patterns and weather conditions. This control group will be used to estimate what demand would have been in the absence of a demand response event. The analysis will include weather normalization to ensure that the baseline reflects the weather conditions experienced during the event. If AMI data is not available for all participants, results will be extrapolated to represent the broader participant population.

DEEMED LIFETIME OF PROGRAM SAVINGS

The expected measure life is assumed to be 1 year.

DEEMED MEASURE COST

The incremental cost of the water heater switch is $149.00.

LOADSHAPE

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

3.9.4 Demand Response Electric Vehicle Charger

DESCRIPTION

This measure characterizes the demand savings achieved by controlling residential electric vehicle (EV) charger loads during peak periods through a demand response (DR) program. Savings impacts will be evaluated using ex-post analysis, primarily leveraging AMI interval data to compare energy consumption during peak periods with and without program intervention.

The evaluation approach includes establishing a control group through propensity score matching with non-participant customers who have similar energy usage patterns and weather conditions. The analysis involves weather normalization to ensure accurate baseline estimations. The demand savings impacts will be determined by comparing the treatment group's energy use during DR events to the weather-normalized baseline.

Due to the custom nature of the evaluation, ex-post demand savings calculations will be based on the specific conditions and data available each year, with previous year results informing program planning and goal setting for subsequent cycles.

This measure was developed to be applicable to the following program type: DR.

DEFINITION OF EFFICIENT CASE

The efficient case is a customer who participates in the DR program, where the EV charger is under the control of the program. In this case, demand reduction is directly influenced by program-driven strategies during peak periods.

DEFINITION OF BASELINE CASE

The baseline case is a customer who is not participating in the DR program and whose EV charger operates independently of program-driven strategies. The baseline for measuring impacts will be established by creating a control group of non-participant customers with similar energy usage patterns and weather conditions. This control group will be used to estimate what demand would have been in the absence of a demand response event. The analysis will include weather normalization to ensure that the baseline reflects the weather conditions experienced during the event. If AMI data is not available for all participants, results will be extrapolated to represent the broader participant population.

DEEMED LIFETIME OF PROGRAM SAVINGS

The expected measure life is assumed to be 1 year.

DEEMED MEASURE COST

Since customers do not need to invest in new equipment or incur additional expenses to participate in the program, the deemed measure cost is $0.

LOADSHAPE

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

3.9.5 Behavioral Demand Response

DESCRIPTION

This measure characterizes the demand savings achieved through a behavioral demand response (DR) program, where participating customers are notified of peak energy use events and encouraged to reduce their energy consumption during these periods. Customers self-manage their energy use in response to notifications, which may be delivered via email, text message, or other communication channels. The program relies on customer action to achieve load reduction during DR events.

Savings impacts will be evaluated using ex-post analysis, primarily leveraging AMI interval data to compare energy consumption during peak periods with and without program participation. The effectiveness of customer actions in response to DR notifications will be assessed to determine the overall demand savings.

The evaluation approach includes establishing a control group through propensity score matching with non-participant customers who have similar energy usage patterns and weather conditions. The analysis involves weather normalization to ensure accurate baseline estimations. Demand savings impacts will be determined by comparing the energy use of participants during DR events to the weather-normalized baseline derived from the control group.

Due to the custom nature of the evaluation, ex-post demand savings calculations will be based on the specific conditions and data available each year, with previous year results informing program planning and goal setting for subsequent cycles.

This measure was developed to be applicable to the following program type: DR.

DEFINITION OF EFFICIENT CASE

The efficient case is a customer who receives notification of behavioral DR program peak energy use events. In this case, demand reduction is directly influenced by the customer’s actions in response to program-driven notifications.

DEFINITION OF BASELINE CASE

The baseline case is a customer who does not receive notification of behavioral DR program peak energy use events. The baseline for measuring impacts will be established by creating a control group of non-participant customers with similar energy usage patterns and weather conditions. This control group will be used to estimate what demand would have been in the absence of a behavioral DR event notification. The analysis will include weather normalization to ensure that the baseline reflects the weather conditions experienced during the event. If AMI data is not available for all participants, results will be extrapolated to represent the broader participant population.

DEEMED LIFETIME OF PROGRAM SAVINGS

The expected measure life is assumed to be 1 year.

DEEMED MEASURE COST

Since customers do not need to invest in new equipment or incur additional expenses to participate in the program, the deemed measure cost is $0.

LOADSHAPE

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A