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.

Volume 3: Residential Measures

3.1 Appliances

3.1.1 Refrigerator and Freezer Recycling

DESCRIPTION
This measure describes savings from the retirement and recycling of inefficient but operational refrigerators and freezers. Savings are provided in two ways. First, a regression equation is provided that requires the use of key inputs describing the retired unit (or population of units) and is based on a 2013 workpaper provided by Cadmus using data from a 2012 ComEd metering study and metering data from a Michigan study. The second methodology is a deemed approach based on 2011 Cadmus analysis of data from a number of evaluations.[1]

The savings are equivalent to the unit energy consumption of the retired unit and should be claimed for the assumed remaining useful life of that unit. A Part Use Factor is applied to account for those secondary units that are not in use throughout the entire year. The user should note that the regression algorithm is designed to provide an accurate portrayal of savings for the population as a whole and includes those parameters that have a significant effect on the consumption. The precision of savings for individual units will vary. 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 type: ERET.

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

DEFINITION OF EFFICIENT EQUIPMENT
N/A

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The estimated remaining useful life of the recycling units is 8 years.[2]

DEEMED MEASURE COST
Measure cost includes the cost of pickup and recycling of the refrigerator and should be based on actual costs of running the program. If unknown, assume $140 per unit.[3]

LOADSHAPE
Refrigeration RES
Freezer RES

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

<u>Regression analysis: Refrigerators</u>

[1] Cadmus "2010 Residential Great Refrigerator Roundup Program – Impact Evaluation," 2011.
[2] KEMA "Residential Refrigerator Recycling Ninth Year Retention Study," 2004.
[3] Based on average program costs for SCE Refrigerator Appliance Recycling Program. Innovologie, "Appliance Recycling Program Retailer Trial Final Report," a report prepared for Southern California Edison, 2013.

Daily energy savings for refrigerators are based upon a linear regression model using the following coefficients:[4]

Independent Variable Description	Estimate Coefficient
Intercept	0.5822
Age (years)	0.0269
Pre-1990 (=1 if manufactured pre-1990)	1.0548
Size (cubic feet)	0.0673
Dummy: Side-by-Side (= 1 if side-by-side)	1.0706
Dummy: Single Door (= 1 if single door)	-1.9767
Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit)	0.6046
Interaction: Located in Unconditioned Space x CDD/365	0.0200
Interaction: Located in Unconditioned Space x HDD/365	-0.0447

$$\Delta kWh_{Unit} = \Big[0.5822 + (Age * 0.0269) + (Pre-1990 * 1.0548) + (Size * 0.0673) + (Side-by-side * 1.0706) + (Single-door * -1.9767) + (Primary\ Usage * 0.6046) + \left(\frac{CDD}{365} * Unconditioned * 0.0200\right) + \left(\frac{HDD}{365} * Unconditioned * -0.0447\right)\Big] * Days * Part\ Use\ Factor$$

Where:

Age = Age of retired unit
Pre-1990 = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)
Size = Capacity (cubic feet) of retired unit
Side-by-Side = Side-by-side dummy (= 1 if side-by-side, else 0)
Single-Door = Single-door dummy (= 1 if single-door, else 0)
Primary Usage = Primary Usage Type (in absence of the program) dummy (= 1 if Primary, else 0)
CDD = Cooling Degree Days
= 1678:[5]

Unconditioned = If unit in unconditioned space = 1, otherwise 0
HDD = Heating Degree Days
= 4486[6]
Days = Days per year
= 365
Part Use Factor = To account for those units that are not running throughout the entire year. If available, Part-Use Factor participant survey results should be used. If not available, assume 0.87.[7]

<u>Deemed approach: Refrigerators</u>

$$\Delta kWh_{Unit} = UEC * Part\ Use\ Factor$$

Where:

UEC = Unit Energy Consumption
= 1181 kWh[8]
Part Use Factor = To account for those units that are not running throughout the entire year. If available, Part-Use Factor participant survey results should be used. If not available, assume 0.87.[9]
ΔkWh_{Unit} = 1181 * 0.87
= 1028 kWh

[4] Coefficients provided in May 13, 2016, Cadmus evaluation report; Ameren Missouri Refrigerator Recycling Impact and Process Evaluation: Program Year 2015.
[5] Based on climate normals CDD data, with a base temp of 65°F.
[6] Based on climate normals HDD data, with a base temp of 65°F.
[7] Most recent refrigerator Part Use Factor from Ameren Missouri PY15 evaluation.
[8] This value is taken from the 2016 Cadmus evaluation of Ameren Missouri Refrigerator Recycling Program Year 2015.
[9] Most recent refrigerator Part Use Factor from Ameren Missouri PY15 evaluation.

Regression analysis: Freezers:

Daily energy savings for freezers are based upon a linear regression model using the following coefficients:[10]

Independent Variable Description	Estimate Coefficient
Intercept	-0.8918
Age (years)	0.0384
Pre-1990 (=1 if manufactured pre-1990)	0.6952
Size (cubic feet)	0.1287
Chest Freezer Configuration (=1 if chest freezer)	0.3503
Interaction: Located in Unconditioned Space x CDD	0.0695
Interaction: Located in Unconditioned Space x HDD	-0.0313

$$\Delta kWh_{Unit} = [-0.8918 + (Age * 0.0384) + (Pre-1990 * 0.6952) + (Size * 0.1287) + (Chest\ Freezer * 0.3503) + (CDD/365 * Unconditioned * 0.0695) + (HDD/365 * Unconditioned * -0.0313)] * Part\ Use\ Factor$$

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

CDD = Cooling Degree Days (see table in refrigerator section)

Unconditioned = If unit in unconditioned space = 1, otherwise 0

HDD = Heating Degree Days (see table in refrigerator section)

Days = Days per year
= 365

Part Use Factor = To account for those units that are not running throughout the entire year. If available, Part-Use Factor participant survey results should be used. If not available, assume 0.84.[11]

Deemed approach: Freezers

$$\Delta kWh_{Unit} = UEC * Part\ Use\ Factor$$

Where:

$UEC_{Reitred}$ = Unit Energy Consumption of retired unit
= 1061 kWh[12]

Part Use Factor = To account for those units that are not running throughout the entire year. If available, Part-Use Factor participant survey results should be used. If not available, assume 0.84.[13]

ΔkWh_{Unit} = 1061 * 0.85
= 891 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh_{unit} = Savings provided in algorithm above (not including $\Delta kWh_{wasteheat}$)

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor[14]
Refrigerators = 0.0001285253
Freezers = 0.0001285253

[10] Coefficients provided in May 13, 2016, Cadmus evaluation report; Ameren Missouri Refrigerator Recycling Impact and Process Evaluation: Program Year 2015.
[11] Most recent refrigerator Part Use Factor from Ameren Missouri PY15 evaluation.
[12] This value is taken from the 2016 Cadmus evaluation of Ameren Missouri refrigerator recycling program year 2015.
[13] Most recent refrigerator part-use factor from Ameren Missouri PY15 evaluation.
[14] Based on Ameren Missouri 2016 Loadshape for Residential Refrigeration and Freezer End-Use.

NATURAL GAS SAVINGS

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

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

If unknown, assume 0

HF = Heating Factor or percentage of reduced waste heat that must now be heated

= 58% for unit in heated space[15]

= 0% for unit in heated space or unknown

$\eta Heat_{Gas}$ = Efficiency of heating system

=71%[16]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[17]

0.03412 = Converts kWh to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[15] Based on 212 days where HDD 65>0, divided by 365.25.

[16] 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.

[17] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls.”

3.1.2 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 and 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.

1. Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust[18] to be considered under this specification.
2. Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)
3. Standby Power Requirement: = 2.0 Watts Qualifying models that perform secondary consumer functions (e.g., clock, remote control) must meet the Standby Power Requirement.
4. 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.[19]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The measure life is assumed to be 9 years.[20]

DEEMED MEASURE COST
The incremental cost for this measure is $70.[21]

LOADSHAPE
Miscellaneous RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[22]

$$Energy\ Savings\ (kWh\ Year) = \{CADR \times (1EffBL - 1EffES) \times (Hroper) + (SBBL - SBES) \times (24 - Hroper)\} \times 365/1000$$

Where:

CADR = Clean air recovery rate for dust
EffBL = Clean air recovery rate for dust per watt for baseline unit
EffES = Clean air recovery rate for dust per watt for ENERGY STAR® unit
Hroper = Hours per day of operation
SBBL = Standby for baseline unit
SBES = Standby for ENERGY STAR® unit
365 = Days/year

[18] Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard.
[19] As defined as the average of non-ENERGY STAR® products found in EPA research, 2011, ENERGY STAR® Qualified Room Air Cleaner Calculator.
[20] ENERGY STAR® Qualified Room Air Cleaner Calculator.
[21] Ameren Missouri MEEIA 2016-18 TRM, January 1, 2018.
[22] ENERGY STAR® Qualified Room Air Cleaner Calculator.

1,000 = Conversion factor (Wh/kWh)

Term	Value
CADR	144.42
EFF_{BL}	1.00
EFF_{ES}	2.91
Hr_{oper}	16
SB_{BL}	1.00
SB_{ES}	0.293

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

CF = 0.0004660805

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

There are no operation and maintenance cost adjustments for this measure.[23]

Measure Code:

[23] 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.

3.1.3 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.[24] 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.[25]

DEEMED MEASURE COST

Dryer Size	Incremental Cost[26]
Standard	$75
Compact	$105

LOADSHAPE

Miscellaneous RES

[24] 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

[25] 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

[26] Cost based on ENERGY STAR® Savings Calculator for ENERGY STAR® Qualified Appliances. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{Load}{CEFbase} - \frac{Load}{CEFeff}\right) * Ncycles * \%Electric$$

Where:

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

Dryer Size	Load (lbs)[27]
Standard	8.45
Compact	3

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR® analysis.[28] 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[29]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR® unit based on ENERGY STAR® requirements.[30] If product class unknown, assume electric, standard.

Product Class	CEFeff
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	3.93
Vented or Ventless Electric, Compact (120V) (< 4.4	3.80
Vented Electric, Compact (240V) (< 4.4 ft^3)	3.45
Ventless Electric, Compact (240V) (< 4.4 ft^3)	2.68
Vented Gas	3.48[31]

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year.[32]

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 5% for gas dryers[33]

Using defaults provided above:

Product Class	kWh
Vented Electric, Standard (≥ 4.4 ft^3)	145.7
Vented Electric, Compact (120V) (< 4.4 ft^3)	53.8
Vented Electric, Compact (240V) (<4.4 ft^3)	58.9
Ventless Electric, Compact (240V) (<4.4 ft^3)	74.3
Vented Gas	7.0

[27] Based on ENERGY STAR® test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[28] ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis.
[29] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[30] ENERGY STAR® Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[31] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[32] Appendix D to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Dryers.
[33] One hundred percent for electric dryers 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.

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

Using defaults provided above:

Product Class	kW
Vented Electric, Standard (≥ 4.4 ft^3)	0.0251
Vented Electric, Compact (120V) (< 4.4	0.0092
Vented Electric, Compact (240V) (<4.4 ft^3)	0.0101
Ventless Electric, Compact (240V) (<4.4	0.0128
Vented Gas	0.0012

NATURAL GAS ENERGY SAVINGS

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

$$\Delta Therm = \left(\frac{Load}{CEFbase} - \frac{Load}{CEFeff}\right) * Ncycles * Therm\_convert * \%Gas$$

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[34]

Using defaults provided above:

ΔTherm = (8.45/2.84 – 8.45/3.48) * 257 * 0.03413 * 0.84
= 4.03 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[34] 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.

3.1.4 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 Tier 3 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 Tier 3 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 March 2015.[35]

Efficiency Level		Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft
Baseline	Federal Standard	≥1.29 IMEF, ≤8.4 IWF	≥1.84 IMEF, ≤4.7 IWF
Efficient	ENERGY STAR®, CEE Tier 1	≥2.06 IMEF, ≤4.3 IWF	≥2.38 IMEF, ≤3.7 IWF
	ENERGY STAR® Most Efficient, CEE Tier 2	≥2.76 IMEF, ≤3.5 IWF	≥2.74 IMEF, ≤3.2 IWF
	CEE Tier 3	≥2.92 IMEF, ≤3.2 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."[36]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years.[37]

DEEMED MEASURE COST

The incremental cost assumptions are provided below:[38]

Efficiency Level	Incremental Cost
ENERGY STAR®, CEE Tier 1	$32
ENERGY STAR® Most Efficient, CEE TIER 2	$393
CEE TIER 3	$454

[35] See http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.
[36] Definitions provided in ENERGY STAR® v7.1 specification on the ENERGY STAR® website.
[37] Based on DOE Chapter 8 Life-Cycle Cost and Payback Period Analysis.
[38] Based on weighted average of top loading and front loading units (based on available product from the California Energy Commission (CEC) Appliance database (https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool. See "2015 Clothes Washer Analysis.xls" for details.

LOADSHAPE

Miscellaneous RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left[\left(Capacity * \frac{1}{IMEFbase} * Ncycles\right) * \left(\%CWbase + (\%DHWbase * \%Electric_{DHW}) + (\%Dryerbase * \%Electric_{Dryer})\right)\right] - \left[\left(Capacity * \frac{1}{IMEFeff} * Ncycles\right) * \left(\%CWeff + (\%DHWeff * \%Electric_{DHW}) + (\%Dryereff * \%Electric_{Dryer})\right)\right]$$

Where:

Capacity = Clothes washer capacity (cubic feet)

= Actual - If capacity is unknown, assume 3.45 cubic feet [39]

IMEFbase = Integrated Modified Energy Factor of baseline unit

Efficiency Level	IMEFbase		
	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft	Weighted Average[40]
Federal Standard	1.29	1.84	1.66

IMEFeff = Integrated Modified Energy Factor of efficient unit

= Actual. If unknown, assume average values provided below.

Efficiency Level	IMEFeff		
	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft	Weighted Average[41]
ENERGY STAR®, CEE Tier 1	2.06	2.38	2.26
ENERGY STAR® Most Efficient, CEE Tier 2	2.76	2.74	2.74
CEE Tier 3	2.92		2.92

Ncycles = Number of Cycles per year

= 271[42]

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

[39] 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). 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.

[40] Weighted average IMEF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR® product in the CEC database (accessed 08/28/2014). The relative weightings are as follows, see more information in "2015 Clothes Washer Analysis.xlsx":

Efficiency Level	Front	Top
Baseline	67%	33%
ENERGY STAR®, CEE Tier 1	62%	38%
ENERGY STAR® Most Efficient, CEE Tier 2	98%	2%
CEE Tier 3	100%	0%

[41] Weighting is based upon the relative top vs. front loading percentage of available product in the CEC database (accessed 08/28/2014).

[42] 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.xls" 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.

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

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

	Percentage of Total Energy Consumption[43]		
	%CW	%DHW	%Dryer
Federal Standard	8%	31%	61%
ENERGY STAR®, CEE Tier 1	8%	23%	69%
ENERGY STAR® Most Efficient, CEE Tier 2	14%	10%	76%
CEE Tier 3	14%	10%	76%

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

DHW fuel	$\%Electric_{DHW}$
Electric	100%
Natural Gas	0%
Unknown	43%[44]

$\%Electric_{Dryer}$ = Percentage of dryer savings assumed to be electric

Dryer fuel	$\%Electric_{Dryer}$
Electric	100%
Natural Gas	0%
Unknown	90%[45]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:[46]

Front Loaders:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	149.3	52.6	96.4	-0.2
ENERGY STAR® Most Efficient, CEE Tier 2	222.1	85.9	132.2	-4.0
CEE Tier 3	243.1	104.8	137.2	-1.1

Top Loaders:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	149.3	97.0	77.0	24.8
ENERGY STAR® Most Efficient, CEE Tier 2	222.1	132.6	117.1	27.5
CEE Tier 3	243.1	374.4	230.5	42.0

[43] The percentage of total energy consumption that is used for the machine, heating the hot water, or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front-loading units based on data from DOE Life-Cycle Cost and Payback Analysis. See "2015 Clothes Washer Analysis.xls" for details.

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

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

[46] Note that the baseline savings for all cases (front, top and weighted average) is based on the weighted average baseline IMEF (as opposed to assuming front baseline for front-efficient unit and top baseline for top- efficient unit). The reasoning is that the support of the program of more efficient units (which are predominately front loading) will result in some participants switching from planned purchase of a top loader to a front loader.

Weighted Average:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	149.3	70.6	88.0	9.4
ENERGY STAR® Most Efficient, CEE Tier 2	222.1	80.9	137.5	-3.7
CEE Tier 3	243.1	98.4	143.2	-1.5

If the DHW and dryer fuel is unknown, the prescriptive kWH savings based on defaults provided above should be:

	ΔkWH		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR®, CEE Tier 1	112.8	89.6	99.0
ENERGY STAR® Most Efficient, CEE Tier 2	161.5	136.6	134.3
CEE Tier 3	424.6	154.8	151.8

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy savings as calculated above

CF = Summer peak coincidence factor for measure

= 0.0001148238

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

Front Loaders:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.022	0.008	0.015	0.000
ENERGY STAR® Most Efficient, CEE Tier 2	0.033	0.013	0.020	-0.001
CEE Tier 3	0.037	0.016	0.021	0.000

Top Loaders:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.022	0.015	0.012	0.004
ENERGY STAR® Most Efficient, CEE Tier 2	0.033	0.020	0.018	0.004
CEE Tier 3	0.037	0.056	0.035	0.006

Weighted Average:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.022	0.011	0.013	0.001
ENERGY STAR® Most Efficient, CEE Tier 2	0.033	0.012	0.021	-0.001
CEE Tier 3	0.037	0.015	0.022	0.000

If the DHW and dryer fuel is unknown, the prescriptive kW savings should be:

	ΔkW		
Efficiency Level	**Front Loaders**	**Top Loaders**	**Weighted Average**
ENERGY STAR®, CEE Tier 1	0.013	0.017	0.015
ENERGY STAR® Most Efficient, CEE Tier 2	0.021	0.024	0.020
CEE Tier 3	0.023	0.064	0.023

NATURAL GAS SAVINGS

$$\Delta Therms = \left[\left[\left(Capacity * \frac{1}{IMEFbase} * Ncycles\right) * \left((\%DHWbase * \%Natural\,Gas_{DHW} * R\_eff) + (\%Dryerbase * \%Gas_{Dryer}\%Gas\,\_Dryer)\right)\right] - \left[\left(Capacity * \frac{1}{IMEFeff} * Ncycles\right) * \left((\%DHWeff * \%Gas_{DHW}\%Natural\,Gas\_DHW * R\_eff) + (\%Dryereff * \%Gas_{Dryer}\%Gas\_Dryer)\right)\right]\right] * Therm\_convert$$

Where:

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

DHW fuel	$\%Gas_{DHW}$
Electric	0%
Natural Gas	100%
Unknown	57%[47]

R_eff = Recovery efficiency factor
= 1.26[48]

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

Dryer fuel	$\%Gas_{Dryer}$
Electric	0%
Natural Gas	100%
Unknown	10%[49]

Therm_convert = Conversion factor from kWh to therm
= 0.03412

Other factors as defined above.

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

	ΔTherms			
	Electric DHW Electric Dryer	**Gas DHW Electric Dryer**	**Electric DHW Gas Dryer**	**Gas DHW Gas Dryer**
ENERGY STAR®, CEE Tier 1	0.0	2.2	2.5	4.7
ENERGY STAR® Most Efficient, CEE Tier 2	0.0	3.8	3.6	7.4
CEE Tier 3	0.0	8.1	11.3	19.4

[47] Default assumption for unknown fuel is based EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then that should be used.
[48] 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. (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore, a factor of 0.98/0.78 (1.26) is applied.
[49] Default assumption for unknown fuel is based EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then that should be used.

Top Loaders:

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.0	4.2	1.8	6.0
ENERGY STAR® Most Efficient, CEE Tier 2	0.0	5.9	3.1	8.9
CEE Tier 3	0.0	5.9	3.6	9.6

Weighted Average:

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.0	3.4	2.1	5.5
ENERGY STAR® Most Efficient, CEE Tier 2	0.0	6.1	2.9	9.0
CEE Tier 3	0.0	6.2	3.4	9.6

If the DHW and dryer fuel is unknown, the prescriptive therm savings should be:

	ΔTherms		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR®, CEE Tier 1	1.51	2.52	2.11
ENERGY STAR® Most Efficient, CEE Tier 2	2.52	3.60	3.71
CEE Tier 3	5.66	3.70	3.84

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water\ (gallons) = Capacity * (IWFbase - IWFeff) * Ncycles$$

Where:

IWFbase = Integrated Water Factor of baseline clothes washer
= 5.92[50]

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

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

	IWF[51]			ΔWater (gallons per year)		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average	Front Loaders	Top Loaders	Weighted Average
Federal Standard	4.7	8.4	5.92	N/A		
ENERGY STAR®, CEE Tier 1	3.7	4.3	3.93	934	3,828	1,857
ENERGY STAR® Most Efficient, CEE Tier 2	3.2	3.5	3.21	1,400	4,575	2,532
CEE Tier 3	3.2		3.20	1,400	7,842	2,538

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[50] 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.

[51] IWF values are the weighted average of the new ENERGY STAR® specifications. Weighting is based upon the relative top vs. front loading percentage of available ENERGY STAR® and ENERGY STAR® Most Efficient products in the CEC database. See "2015 Clothes Washer Analysis.xls" for the calculation.

3.1.5 Dehumidifier

DESCRIPTION

A dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR® Version 4.0 (effective 2/1/2016) 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 and NC.

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

DEFINITION OF EFFICIENT EQUIPMENT

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

Capacity (pints/day)	ENERGY STAR® Criteria (L/kWh)
<75	≥2.00
75 to ≤185	≥2.80

Qualifying units must be equipped with an adjustable humidistat control or must have a remote humidistat control to operate.

DEFINITION OF BASELINE EQUIPMENT

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

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the measure is 12 years.[52]

DEEMED MEASURE COST

The assumed incremental capital cost for this measure is $5.[53]

LOADSHAPE

Cooling RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

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

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

[52] Lifetime determined by EPA research, 2012. ENERGY STAR® Qualified Room Air Cleaner Calculator. (ENERGY STAR® Appliance Calculator.xlsx).

[53] Incremental costs determined by EPA research on available models, July 2016. ENERGY STAR® Qualified Room Air Cleaner Calculator. (ENERGY STAR® Appliance Calculator.xlsx).

0.473 = Constant to convert Pints to Liters
24 = Constant to convert Liters/day to Liters/hour
Hours = Run hours per year
= 1632[54]
L/kWh = Liters of water per kWh consumed, as provided in tables above

Annual kWh results for each capacity class are presented below:

Capacity Range (pints/day)	Capacity Used (pints/day)	Federal Standard Criteria (≥ L/kWh)	ENERGY STAR® Criteria (≥ L/kWh)	Annual kWh: Federal Standard	Annual kWh: ENERGY STAR®	Annual kWh: Savings
≤25	20	1.35	2.0	477	322	155
> 25 to ≤35	30	1.35	2.0	714	482	232
> 35 to ≤45	40	1.5	2.0	857	643	214
> 45 to ≤ 54	50	1.6	2.0	1005	804	201
> 54 to ≤ 75	65	1.7	2.0	1,229	1,045	184
> 75 to ≤ 185	130	2.5	2.8	1,672	1,493	179
Average[55]						204

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

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

Capacity (pints/day) Range	Annual Summer peak kW Savings
≤25	0.095
> 25 to ≤35	0.142
> 35 to ≤45	0.131
> 45 to ≤ 54	0.123
> 54 to ≤ 75	0.113
> 75 to ≤ 185	0.110
Average	0.125

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[54] Based on 24-hour operation over 68 days of the year. ENERGY STAR® Qualified Room Air Cleaner Calculator. (ENERGY STAR® Appliance Calculator.xlsx).

[55] The relative weighting of each product class is based on number of units on the ENERGY STAR® certified list. See "Dehumidifier Calcs.xls."

3.1.6 Dehumidifier Recycling

DESCRIPTION

This measure describes the savings resulting from the retirement of existing residential, inefficient dehumidifier units from service prior to end of their natural life. This measure assumes that a percentage of these units will be replaced with a baseline standard efficiency unit (note that if the unit is actually replaced by a new ENERGY STAR® qualifying unit, the savings increment between baseline and ENERGY STAR® will be recorded in the Efficient Products program).

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing inefficient dehumidifier unit.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 5 years.

DEEMED MEASURE COST

The incremental cost for this measure is $42.76.

LOADSHAPE

HVAC RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[56]

Program Deemed Savings estimate:

Gross Electric Savings (kWh/unit)		Gross Demand Savings (kW/home)
139		.0648

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

CF = 0.0004660805

MEASURE CODE:

[56] Deemed value per 2018 MEMD database for a drop-off program.

3.1.7 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.

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
Baseline efficiency is a new refrigerator meeting the minimum federal efficiency standard for refrigerators effective September 15th, 2014, for all programs except low-income direct install programs. For low-income programs, the baseline is the existing equipment.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
17 years[57]

DEEMED MEASURE COST
The full cost of a baseline unit is $742.[58]
The incremental cost to the ENERGY STAR® level is $11, to CEE Tier 2 level is $20, and to CEE Tier 3 is $59.[59]

LOADSHAPE
Refrigeration RES

[57] Mean from Figure 8.2.3, DOE, 2011 - 08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers. http://www.regulations.gov/contentStreamer?objectId=0900006480f0c7df&disposition=attachment&contentType=pdf
[58] 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. http://www.regulations.gov/contentStreamer?objectId=0900006480f0c7df&disposition=attachment&contentType=pdf
[59] Configurations weighted according to table under Energy Savings. Values inflated 8.9% from 2009 dollars to 2015. Table 8.2.2, DOE, 2011-08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers. http://www.regulations.gov/contentStreamer?objectId=0900006480f0c7df&disposition=attachment&contentType=pdf

Algorithm

Calculation of Savings

Electric Energy Savings

Savings by model may be pulled directly from ENERGY STAR® data. Alternatively, savings by product class may be calculated according to the algorithm below:

$$\Delta kWh_{Unit} = kWh_{\text{base}} - (kWh_{\text{base}} * (1 - \%Savings))$$

Where:

kWh_{base} = Baseline consumption,[60] assuming 22.5 ft^3 adjusted volume[61]

= Calculated using algorithms in table below, or using defaults provided based on 22.5 ft^3 adjusted volume[62]

%Savings = Specification of energy consumption below Federal Standard:

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

For low-income programs, the following table may be used to calculate baseline usage:

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 [63]

= 0% for unit in unheated space

$\eta Heat_{Electric}$ = Efficiency in COP of Heating equipment

= Actual - If not available, use table below:[64]

[60] According to Federal Standard effective 9/15/14.
[61] DOE Building Energy Data Book, http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.5.
[62] DOE Building Energy Data Book, http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.5.
[63] Based on 212 days where HDD 65>0, divided by 365.25.
[64] 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.

System Type	Age of Equipment	HSPF Esitmate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.28[65]

%ElecHeat = Percentage of home with electric heat

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	35%[66]

WHFeCool = Waste Heat Factor for Energy to account for cooling savings from removing waste heat from refrigerator/freezer.

= (CoolF / ηCool) * %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 [67]

= 0% for unit in uncooled space

ηCool = Efficiency in COP of Cooling equipment

= Actual - If not available, assume 2.8 COP[68]

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91%[69]

Algorithms for the most common refrigerator configurations, kWh_{base}, $\Delta kWh_{WasteHeat}$ for unknown building characteristics and resulting deemed ΔkWh savings is provided below:

Product Class	Algorithm from Federal Standard	Baseline Usage kWh_{base}	Unit ΔkWh			$\Delta kWh_{WasteHeat}$			Total ΔkWh		
			ENERGY STAR® / CEE Tier 1	CEE Tier 2	CEE Tier 3	ENERGY STAR® / CEE Tier 1	CEE Tier 2	CEE Tier 3	ENERGY STAR® / CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	8.40AV + 385.4	574	57.4	86.1	114.8	-0.9	-1.4	-1.9	56.5	84.7	112.9
Side-by-Side w/ TTD (PC 7)	8.54AV + 432.8	625	62.5	93.75	125	-1.0	-1.5	-2.1	61.5	92.2	122.9
Bottom Freezer (PC 5)	8.85AV + 317.0	516	51.6	77.4	103.2	-0.8	-1.3	-1.7	50.8	76.1	101.5
Bottom Freezer w/ TTD (PC 5A)	9.25AV + 475.4	684	68.4	102.6	136.8	-1.1	-1.7	-2.2	67.3	100.9	134.6

[65] Calculation assumes 13% heat pump and 87% resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls." Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.

[66] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls."

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

[68] 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.

[69] Based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region.xls."

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:

<table>
<tr><th rowspan="2">Product Class</th><th rowspan="2">Market Weight[70]</th><th colspan="3">Unit ΔkWh</th><th colspan="3">ΔkWh_{WasteHeat}</th><th colspan="3">Total ΔkWh</th></tr>
<tr><th>Energy Star®/ CEE Tier 1</th><th>CEE Tier 2</th><th>CEE Tier 3</th><th>Energy Star®/ CEE Tier 1</th><th>CEE Tier 2</th><th>CEE Tier 3</th><th>Energy Star®/ CEE Tier 1</th><th>CEE Tier 2</th><th>CEE Tier 3</th></tr>
<tr><td>Top Freezer (PC 3)</td><td>52%</td><td rowspan="4">59.2</td><td rowspan="4">88.8</td><td rowspan="4">118.4</td><td rowspan="4">-1.0</td><td rowspan="4">-1.5</td><td rowspan="4">-1.9</td><td rowspan="4">58.2</td><td rowspan="4">87.3</td><td rowspan="4">116.5</td></tr>
<tr><td>Side-by-Side w/ TTD (PC 7)</td><td>22%</td></tr>
<tr><td>Bottom Freezer (PC 5)</td><td>13%</td></tr>
<tr><td>Bottom Freezer w/ TTD (PC 5A)</td><td>13%</td></tr>
</table>

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\Delta kWh_{WasteHeatCooling}\right) * CF$$

Where:

$\Delta kWh_{WasteHeatCooling}$ = gross customer connected load kWh savings for the measure. Including any cooling system savings.

CF = Summer Peak Coincident Factor

= 0.0001285253[71]

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

Product Class	ΔkW		
	Energy Star®/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	0.0086	0.0130	0.0173
Side-by-Side w/ TTD (PC 7)	0.0094	0.0141	0.0188
Bottom Freezer (PC 5)	0.0078	0.0117	0.0155
Bottom Freezer w/ TTD (PC 5A)	0.0103	0.0155	0.0206

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:

<table>
<tr><th rowspan="2">Product Class</th><th rowspan="2">Market Weight[72]</th><th colspan="3">ΔkW</th></tr>
<tr><th>Energy Star®/ CEE Tier 1</th><th>CEE Tier 2</th><th>CEE Tier 3</th></tr>
<tr><td>Top Freezer (PC 3)</td><td>52%</td><td rowspan="4">0.0089</td><td rowspan="4">0.0134</td><td rowspan="4">0.0178</td></tr>
<tr><td>Side-by-Side w/ TTD (PC 7)</td><td>22%</td></tr>
<tr><td>Bottom Freezer (PC 5)</td><td>13%</td></tr>
<tr><td>Bottom Freezer w/ TTD (PC 5A)</td><td>13%</td></tr>
</table>

70 Personal Communication from Melisa Fiffer, ENERGY STAR® Appliance Program Manager, EPA 10/26/14.
71 Based on Ameren Missouri 2016 Loadshape for Residential Refrigeration End-Use.
72 Personal Communication from Melisa Fiffer, ENERGY STAR® Appliance Program Manager, EPA 10/26/1.4.

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[73]

= 0% for unit in unheated space

$\eta Heat_{Gas}$ = Efficiency of heating system

=74%[74]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[75]

0.03412 = Converts kWh to therms

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:

Product Class	Market Weight[76]	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:

[73] Based on 212 days where HDD 65>0, divided by 365.25.

[74] 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.

[75] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls."

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

3.1.8 Room Air Conditioner Recycling

DESCRIPTION

This measure describes the savings resulting from the retirement of existing residential, inefficient room air conditioner units from service prior to their natural end of life. This measure assumes that a percentage of these units will be replaced with a baseline standard efficiency unit (note that if it is actually replaced by a new ENERGY STAR® qualifying unit, the savings increment between baseline and ENERGY STAR® will be recorded in the Efficient Products program).

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed remaining useful life of the existing room air conditioning unit being retired is 4 years.[77]

DEEMED MEASURE COST

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

LOADSHAPE

Cooling RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kWhexist - (\%replaced * kWhnewbase)$$

$$= \frac{Hours * BtuH}{EERexist * 1000} - (\%replaced * \frac{Hours * BtuH}{EERNewBase * 1000})$$

Where:

Hours = Full Load Hours of room air conditioning unit

Weather Basis (City based upon)	Hours[78]
St Louis, MO	860 for primary use and 556 for secondary use

BtuH = Average size of rebated unit. Use actual if available - if not, assume 8500[79]

EERexist = Efficiency of recycled unit

[77] One third of assumed measure life for room air conditioners.

[78] Ameren Missouri PY 2013 Coolsavers evaluation. http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) to FLH for Central Cooling for the same locations (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) is 31%. This factor was applied to published CDD65 climate normals data to provide an assumption for FLH for Room AC.

[79] Based on maximum capacity average from the RLW Report; "Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008."

= Actual if recorded - If not, assume 9.0[80]

%replaced = Percentage of units that are replaced

Scenario	%replaced
Customer states unit will not be replaced	0%
Customer states unit will be replaced	100%
Unknown	76%[81]

EERbase = Efficiency of baseline unit

= 10.9[82]

Results using defaults provided above:

Weather Basis (City based upon)	ΔkWh		
	Unit not replaced	Unit replaced	Unknown
St Louis, MO	525.4	91.6	195.7

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.0009474181[83]

Results using defaults provided above:

Weather Basis (City based upon)	DkW		
	Unit not replaced	Unit replaced	Unknown
St Louis, MO	0.4978	0.0868	0.1854

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE

[80] The federal minimum for the most common type of unit (8000 – 13999 Btuh with side vents) from 1990-2000 was 9.0 EER, from 2000-2014 it was 9.8 EER, and is currently (2015) 10.9 CEER. Retirement programs will see a large array of ages being retired, and the true EER of many will have been significantly degraded. We have selected 9.0 as a reasonable estimate of the average retired unit. This is supported by material on the ENERGY STAR® website, which, if reverse-engineered, indicates that an EER of 9.16 is used for savings calculations for a 10-year old room air conditioner. Another statement indicates that units that are at least 10 years old use 20% more energy than a new ES unit, which equates to: 10.9EER/1.2 = 9.1 EER; http://www.energystar.gov/ia/products/recycle/documents/RoomAirConditionerTurn-InAndRecyclingPrograms.pdf.

[81] Based on Nexus Market Research Inc., RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report." Report states that 63% were replaced with ENERGY STAR® units and 13% with non-ENERGY STAR®. However, this formula assumes all are non-ENERGY STAR® since the increment of savings between baseline units and ENERGY STAR® would be recorded by the Efficient Products program when the new unit is purchased.

[82] Minimum federal standard for capacity range and most popular class (without reverse cycle, with louvered sides, and 8,000 to 13,999 Btu/h). http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41.

[83] Based on Ameren Missouri 2016 loadshape for residential cooling end-use.

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.[84]

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.[85]
For DI and KITS, the actual full installation cost of an APS (including equipment and labor) should be used.

LOADSHAPE

Miscellaneous RES

[84] "Advanced Power Strip Research Report," NYSERDA, August 2011.
[85] Incremental cost based on "Advanced Power Strip Research Report." Typical cost of an advanced power strip is $35, and average cost of a standard power strip is $15.

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
= 31.0 kWh[86]

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

Installation Location	$Weighting_{Office}$
Home Office	100%
Home Entertainment System	0%
Unknown[87]	TOS, NC, DI: 36% KITS: 48%

kWh_{Ent} = Estimated energy savings from using an APS in a home entertainment system
= 75.1 kWh[88]

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

Installation Location	$Weighting_{Ent}$
Home Office	0%
Home Entertainment System	100%
Unknown[89]	TOS, NC, DI: 64% KITS: 52%

ISR = In service rate, dependent on program type

Program Type	ISR
TOS, NC, DI	100%
KITS	78%[90]

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

Installation Location	Program Type	ΔkWh
Home Office	TOS, NC, DI	31.0
	KITS	24.2
Home Entertainment System	TOS, NC, DI	75.1
	KITS	58.6
Unknown	TOS, NC, DI	59.2
	KITS	42.1

[86] "Advanced Power Strip Research Report." 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.
[87] 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. If the programs have their own evaluations of weightings, they should be used.
[88] "Advanced Power Strip Research Report."
[89] 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. If the programs have their own evaluations of weightings, they should be used.
[90] "Ameren Missouri Efficient Product Impact and Process Evaluation: Program Year 2015."

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[91]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[91] Based on Ameren Missouri 2016 loadshape 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."

3.2.2 Tier 2 Advanced Power Strip – Residential Audio Visual

DESCRIPTION

This measure applies to the installation of a Tier 2 Advanced Power Strip 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. Using advanced control strategies such as true RMS (Root Mean Square) power sensing, and/or external sensors,[92] both active power loads and standby power loads of controlled devices are managed by Tier 2 AV APS devices. 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 intelligent sensing and control process has been demonstrated to deliver increased energy savings and demand reduction compared with Tier 1 Advanced Power Strips.

The Tier 2 AV APS market is a relatively new and developing one. With several new Tier 2 AV APS products coming to market, it is important that energy savings be clearly demonstrated through independent field trials. Field trial should effectively address the inherent variability in AV system usage patterns. Until there is enough independent evidence to demonstrate deemed savings for each of the various control strategies, it is recommended that products with independent field trial results be placed into performance bands and savings claimed accordingly.

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

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.[93]

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.[94]

DEEMED MEASURE COST

The actual full installation cost of the Tier 2 AV APS (including equipment and labor) should be used.

LOADSHAPE

Miscellaneous RES

[92] Tier 2 AV APS identify when people are not engaged with their AV equipment and then remove power (e.g., a TV and its peripheral devices that are unintentionally left on when a person leaves the house or falls asleep while watching television).

[93] 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.

[94] "Advanced Power Strip Research Report," NYSERDA, August 2011.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

ERP = Energy reduction percentage of qualifying Tier 2 AV APS product Class; see table below:[95]

Product Class	Field Trial ERP Range	ERP Used
A	55 – 60%	55%
B	50 – 54%	50%
C	45 – 49%	45%
D	40 – 44%	40%
E	35 – 39%	35%
F	30 – 34%	30%
G	25 – 29%	25%
H	20 – 24%	20%

$BaselineEnergy_{AV}$ = 432 kWh[96]

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

Product Class	ΔkWh
A	238
B	216
C	194
D	173
E	151
F	130
G	108
H	86

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001148238[97]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

95 Based on field test data for various APS products.

96 "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.

97 Based on Ameren Missouri 2016 loadshape 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."

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 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, 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 (and therefore the freerider rate for this measure should be 0), use of the faucet at less than full flow, debris buildup, and lower water system pressure than fixtures are rated at.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[98]

DEEMED MEASURE COST

The incremental cost for this measure is $11.33[99] or program actual.
For faucet aerators provided in efficiency kits, the actual program delivery costs should be utilized. Absent of program data, use $3.00[100]

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[101] (unless faucet type is unknown, then it is per household).

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_electric * ISR

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	43%[102]

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used." This includes the effect of existing low flow fixtures and therefore the freerider rate for this measure should be 0.

[98] Measure lifetime is derived from the California DEER Effective Useful Life Table – 2014 Table Update. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx

[99] 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.

[100] Illinois TRM.

[101] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.

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

= 1.39[103] or custom based on metering studies[104] or if measured during DI:
= Measured full throttle flow * 0.83 throttling factor[105]

GPM_low = Average flow rate, in gallons per minute, of the low-flow faucet aerator "as-used"
= 0.94[106] or custom based on metering studies[107] or if measured during DI:
= Rated full throttle flow * 0.95 throttling factor[108]

L_base = Average baseline daily length faucet use per capita for faucet of interest in minutes
= if available custom based on metering studies, if not use:

Faucet Type	L_base (min/person/day)
Kitchen	4.5[109]
Bathroom	1.6[110]
If location unknown (total for household): Single-Family	7.8[111]
If location unknown (total for household): Multi-Family	6.7[112]

L_low = Average retrofit daily length faucet use per capita for faucet of interest in minutes
= if available custom based on metering studies, if not use:

Faucet Type	L_low (min/person/day)
Kitchen	4.5[113]
Bathroom	1.6[114]
If location unknown (total for household): Single-Family	7.8[115]
If location unknown (total for household): Multi-Family	6.7[116]

Household = Average number of people per household

Household Unit Type	Household
Single-Family	2.67[117]
School Kits	4.3[118]
Multi-Family - Deemed	2.07[119]
Custom	Actual Occupancy or Number of Bedrooms[120]

[103] Deoreo, B., and P. Mayer, "Residential End Uses of Water Study Update." Forthcoming. ©2015 Water Research Foundation. Reprinted with permission.
[104] 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.
[105] 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. www.seattle.gov/light/Conserve/Reports/paper_10.pdf
[106] Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7 (see source table at end of characterization).This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.
[107] 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.
[108] 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. www.seattle.gov/light/Conserve/Reports/paper_10.pdf
[109] 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.
[110] 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.
[111] One kitchen faucet plus 2.04 bathroom faucets. Based on findings from a 2012 Ameren Missouri potential study for single family homes.
[112] One kitchen faucet plus 1.4 bathroom faucets. Based on findings from Ameren Missouri PY13 data for multifamily homes.
[113] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[114] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[115] One kitchen faucet plus 2.04 bathroom faucets. Based on findings from a 2012 Ameren Missouri potential study for single family homes.
[116] One kitchen faucet plus 1.4 bathroom faucets. Based on findings from an Ameren Missouri PY13 data for multifamily homes.
[117] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.
[118] Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: Program Year 2016.
[119] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.
[120] Bedrooms are suitable proxies for household occupancy and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

365.25 = Days in a year, on average.
DF = Drain Factor

Faucet Type	Drain Factor[121]
Kitchen	75%
Bath	90%
Unknown	79.5%

FPH = Faucets Per Household

Faucet Type	FPH
Kitchen Faucets Per Home (KFPH)	1
Bathroom Faucets Per Home (BFPH): Single-Family	2.04[122]
Bathroom Faucets Per Home (BFPH): School Kits	2.4[123]
Bathroom Faucets Per Home (BFPH): Multi-Family	1.4[124]
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)
8.33 = Specific weight of water (lbs/gallon)
1.0 = Heat Capacity of water (btu/lb-°F)
WaterTemp = Assumed temperature of mixed water
= 86F for Bath, 93F for Kitchen 91F for Unknown[125]
SupplyTemp = Assumed temperature of water entering house
= 60.83F[126]
RE_electric = Recovery efficiency of electric water heater
= 98%[127]
3412 = Converts Btu to kWh (btu/kWh)
ISR = In service rate of faucet aerators dependant on install method as listed in table below

Selection	ISR
Direct Install	0.977[128]
Efficiency Kit—Single Family	0.52[129]
Efficiency Kit—Multi Family	1.0[130]

[121] 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.
[122] Based on findings from a 2012 Ameren Missouri potential study for single family homes.
[123] Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: Program Year 2016.
[124] Based on findings from an Ameren Missouri PY13 data for multifamily homes.
[125] 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.
[126] Based on the DOE's Building America Standard DHW Event Schedule calculator. Average annual water main temperatures were determined for each defined weather zone in Missouri. The overall average of 60.83 is taken to represent the statewide average input water temperature.
[127] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx.
[128] Ameren Missouri Home Energy Analysis Program Impact and Process Evaluation: Program Year 2015.
[129] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015.
[130] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015.

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[131]

NATURAL GAS SAVINGS

$\Delta Therms$ = %GasDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_gas * ISR

Where:

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

DHW fuel	%GasHW
Electric	0%
Natural Gas	100%
Unknown	48%[132]

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[133]

= 67% For MF homes[134]

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

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Variables as defined above.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[131] Based on Ameren Missouri 2016 loadshape for residential water heating end-use.

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

[133] 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%.

[134] 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[135] 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.[136]

DEEMED MEASURE COST

The incremental cost for TOS, NC, or KITS is $7[137] 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.[138]

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

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	43%[139]

[135] 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
[136] 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, http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf.
[137] Based on online pricing market research 2/6/2017.
[138] 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).
[139] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then that should be used.

GPM_base = Flow rate of the baseline showerhead

Program	GPM_base
Direct-install	2.35[140]
Retrofit, Efficiency Kits, NC or TOS	2.35[141]

GPM_low = As-used flow rate of the lowflow showerhead, which may, as a result of measurements of program evaulations deviate from rated flows, see table below:

Rated Flow
2.0 GPM
1.75 GPM
1.5 GPM
Custom or Actual[142]

L_base = Shower length in minutes with baseline showerhead
= 7.8 min[143]

L_low = Shower length in minutes with low-flow showerhead
= 7.8 min[144]

Household = Average number of people per household

Household Unit Type[145]	Household
Single-Family	2.67[146]
School Kits	4.3
Multi-Family	2.07[147]
Custom	Actual Occupancy or Number of Bedrooms[148]

SPCD = Showers Per Capita Per Day
= 0.6[149]

365.25 = Days per year, on average.

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

Household Type	SPH
Single-Family	2.05[150]
School Kits	2.1[151]
Multi-Family	1.4[152]
Custom	Actual

[140] Based on Ameren Missouri PY14 program data for direct-install measures. A delta of 0.85 GPM is assumed, derived from confirmed retrofitted aerator flow rates of 1.5 GPM and assuming existing showerheads were consuming 2.35 GPM, based on average of DOE-reported values for homes with domestic water pressures of 60psi and 80psi. http://energy.gov/energysaver/articles/reduce-hot-water-use-energy-savings.

[141] Representative value from sources 1, 2, 4, 5, 6, and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation, which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

[142] 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.

[143] 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.

[144] 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.

[145] If household type is unknown, as may be the case for TOS measures, then single family deemed value should be used.

[146] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.

[147] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.

[148] 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.

[149] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum, dated June 2013, directed to Michigan Evaluation Working Group.

[150] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.

[151] Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: Program Year 2016.

[152] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.

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
= 101.0 F[153]
SupplyTemp = Assumed temperature of water entering house
= 60.83 F[154]
RE_electric = Recovery efficiency of electric water heater
= 98%[155]
3412 = Converts Btu to kWh (btu/kWh)
ISR = In service rate of showerhead
= Dependant on program delivery method as listed in table below:

Selection	ISR
Direct Install	0.98[156]
Efficiency Kit—Single Family	0.47[157]
Efficiency Kit—Multifamily	0.86[158]

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[159]

NATURAL GAS SAVINGS

ΔTherms = %GasDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

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

DHW fuel	%GasDHW
Electric	0%
Natural Gas	100%
Unknown	48%[160]

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

[153] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated, June 2013, directed to Michigan Evaluation Working Group.
[154] Based on the DOE's Building America Standard DHW Event Schedule calculator. Average annual water main temperatures were determined for each defined weather zone in Missouri. The overall average of 60.83 is taken to represent the statewide average input water temperature.
[155] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx.
[156] Ameren Missouri Home Energy Analysis Program Impact and Process Evaluation: Program Year 2015.
[157] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015.
[158] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015.
[159] Based on Ameren Missouri 2016 loadshape for residential water heating end-use.
[160] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then that should be used.

= 78% For SF homes[161]
= 67% For MF homes[162]
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 * SPCD * 365.25 / SPH) * ISR
Variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[161] 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%.
[162] 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.

3.3.3 Water Heater Wrap

DESCRIPTION

This measure applies to a tank wrap or insulation "blanket" that is wrapped around the outside of an electric or gas domestic hot water (DHW) tank to reduce stand-by 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 an electric or gas DHW tank with wrap installed that has an R-value that meets program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is an uninsulated electric or gas DHW tank.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years.[163]

DEEMED MEASURE COST

The measure cost is the actual cost of material and installation. If actual costs are unknown, assume $58[164] for material and installation.

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below for electric DHW tanks, otherwise use default values from table that follows:

$$\Delta kWh = ((A_{Base}/R_{Base} - A_{EE}/R_{EE}) * \Delta T * Hours)/(\eta DHW_{Elec} * 3{,}412)$$

Where:

A_{Base} = Surface area (ft^2) of storage tank prior to adding tank wrap[165]
= Actual or if unknown, use default based on tank capacity (gal) from table below

R_{Base} = Thermal resistance coefficient (hr-°F-ft^2/BTU) of uninsulated tank
= Actual or if unknown, assume 14[166]

A_{EE} = Surface area (ft^2) of storage tank after addition of tank wrap[167]
= Actual or, if unknown, use default based on tank capacity (gal) from table below

R_{EE} = Thermal resistance coefficient ((hr-°F-ft2/BTU) of tank after addition of tank wrap (R-value of uninsulated tank + R-value of tank wrap)
= Actual or if unknown, assume 24

ΔT = Average temperature difference (°F) between tank water and outside air
= Actual or if unknown, assume 60°F[168]

[163] 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).
[164] Average cost of R-10 tank wrap installation from the National Renewable Energy Laboratory's National Residential Efficiency Measures Database. http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=270.
[165] Area includes tank sides and top to account for typical wrap coverage.
[166] Baseline R-value based on information from Chapter 6 of *The Virginia Energy Savers Handbook*, Third Edition: The best heaters have 2 to 3 inches of urethane foam, providing R-values as high as R-20. Other less expensive models have fiberglass tank insulation with R-values ranging between R-7 and R-10.
[167] Area includes tank sides and top to account for typical wrap coverage.
[168] Assumes 125°F hot water tank temperature and average basement temperature of 65°F.

Hours = Hours per year
= 8,766
ηDHW_{Elec} = Recovery efficiency of electric hot water heater
= Actual or if unknown, assume 0.98[169]
3,412 = Conversion factor from Btu to kWh

The following table contains default savings for various tank capacities.

Capacity (gal)	A_{Base} (ft^2)[170]	A_{EE} (ft^2)[171]	ΔkWh	ΔkW
30	19.16	20.94	78.0	0.00890
40	23.18	25.31	94.6	0.01079
50	24.99	27.06	103.4	0.01180
80	31.84	34.14	134.0	0.01528

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:
ΔkWh = Electric energy savings, as calculated above.
CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0000887318[172]

The table above contains default kW savings for various tank capacities.

NATURAL GAS SAVINGS

Custom calculation below for gas DHW tanks, otherwise use default values from table that follows:

$$\Delta Therms = ((A_{Base}/R_{Base} - A_{EE}/R_{EE}) * \Delta T * Hours)/(\eta DHW_{Gas} * 100{,}000)$$

Where:
ηDHW_{Gas} = Recovery efficiency of gas hot water heater
= 0.78[173]
100,000 = Conversion factor from Btu to therms
Other variables as defined above

The following table contains default savings for various tank capacities.

Capacity (gal)	A_{Base} (ft^2)[174]	A_{EE} (ft^2)[175]	ΔTherms	ΔPeakTherms
30	19.16	20.94	3.3	0.0092
40	23.18	25.31	4.1	0.0111
50	24.99	27.06	4.4	0.0121
80	31.84	34.14	5.7	0.0157

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

169 Electric water heater recovery efficiency from AHRI database: http://www.ahridirectory.org/ahridirectory/pages/home.aspx.
170 Surface area assumptions from the June 2016 Pennsylvania TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
171 Surface area assumptions from the June 2016 Pennsylvania TRM. A_{EE} was calculated by assuming that the water heater wrap is a 2” thick fiberglass material.
172 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Water Heating. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf.”
173 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%.
174 Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage. Recommend updating with Missouri-specific data when available.
175 A_{EE} was calculated by assuming that the water heater wrap is a 2” thick fiberglass material. Recommend updating with Missouri-specific data when available.

3.3.4 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.[176]

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a new, electric storage water heater meeting federal minimum efficiency standards[177] for units ≤55 gallons: 0.96 – (0.0003 * rated volume in gallons).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.[178]

DEEMED MEASURE COST

Actual costs should be used where available. The default value for incremental capital costs is $588.[179]

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{(1/EF_{BASE} - 1/EF_{EE}) * GPD * Household * 365.25 * \gamma Water * (T_{Out} - T_{In}) * 1.0)}{3{,}412}\right) + kWh\_cool - kWh\_heat$$

Where:

EF_{BASE} = EF of standard electric water heater according to federal standards
= 0.96 – (0.0003 * rated volume in gallons)
= If rated volume is unknown, assume 0.945 for a 50-gallon water heater

EF_{EE} = EF of heat pump water heater
= Actual

GPD = Gallons per day of hot water use per person
= 17.6[180]

Household = Average number of people per household

[176] Since the federal standard effectively requires a heat pump water heater for units over 55 gallons, this measure is limited to units ≤ 55 gallons.
[177] Minimum federal standard as of 4/16/2015:
http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.
http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.
[178] 2010 Residential Heating Products Final Rule Technical Support Document, U.S. DOE, Table 8.7.2.
[179] Ameren Missouri MEEIA 2016-18 TRM – January 1, 2018.
[180] 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.

Household Unit Type[181]	Household
Single-Family - Deemed	2.67[182]
Multi-Family - Deemed	2.07[183]
Custom	Actual Occupancy or Number of Bedrooms[184]

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
= 57.898°F[185]

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

3,412 = Conversion factor from Btu to kWh

kWh_cool = Cooling savings from conversion of heat in home to water heat[186]

$$= \left[\frac{\left(\left(1 - \frac{1}{EF_{EE}}\right) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 40\% * LM}{COP_{COOL} * 3{,}412} \right] * \%Cool$$

Where:

LF = Location Factor
= 1.0 for HPWH installation in a conditioned space
= 0.0 for installation in an unconditioned space

40% = Portion of reduced waste heat that results in cooling savings[187]

COP_{COOL} = COP of central air conditioner
= Actual, or if unknown, assume 2.8 COP[188]

LM = Latent multiplier to account for latent cooling demand [189]

Weather Basis (City based upon)	LM
St Louis, MO	3.0

%Cool = Percentage of homes with central cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91%[190]

[181] If household type is unknown, as may be the case for TOS measures, then single family deemed value shall be used.
[182] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, prepared by Cadmus.
[183] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, prepared by Cadmus.
[184] 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.
[185] Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12-month average is 57.898. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061.
[186] 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.
[187] Based on 148 days where CDD 65>0, divided by 365.25. CDD days determined with a base temp of 65°F.
[188] 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.
[189] 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.
[190] Based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region.xls."

kWh_heat = Heating cost from conversion of heat in home to water heat (dependent on heating fuel)

$$= \left(\frac{\left(\left(1 - \frac{1}{EF_{EE}} \right) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 58\%}{COP_{HEAT} * 3{,}412} \right) * \%ElectricHeat$$

Where:

58% = Portion of reduced waste heat that results in increased heating load[191]

COP_{HEAT} = COP of electric heating system

= Actual, or if unknown, assume:[192]

System Type	Age of Equipment	Heating Seasonal Performance Factor (HSPF) Estimate	COP (Effective COP Estimate) (HSPF/3.412)* 0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 and after	8.2	2.04
Resistance	N/A	N/A	1

%ElectricHeat = Percentage of home with electric heat

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[193]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

kWh = Electric energy savings, as calculated above

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

= 0.0000887318[194]

NATURAL GAS SAVINGS

$$\Delta Therms = -\left(\frac{\left(\left(1 - \frac{1}{EF_{EE}} \right) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 43\%}{\eta Heat * 100{,}000} \right) * \%GasHeat$$

Where:

ΔTherms = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat[195]

100,000 = Conversion factor from Btu to therms

ηHeat = Efficiency of heating system

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[191] Based on 212 days where HDD 65>0, divided by 365.25.

[192] 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.

[193] 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.

[194] Based on Ameren Missouri 2016 loadshape for residential water heating end-use.

[195] 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.

= 71%[196]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[197]

Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[196] 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 "HC6.9 Space Heating in Midwest Region.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.

[197] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls."

3.3.5 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 pipe up to the first elbow. This is the most cost-effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow, which acts as a heat trap. Insulating this 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.[198]

DEEMED MEASURE COST

The measure cost is the actual cost of material and installation. If the actual cost is unknown, assume a default cost of $7.10 [199] per linear foot, including material and installation. For a kit program, assume a default cost of $2.87.[200]

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:

$$\Delta kWh = ((C_{Base}/R_{Base} - C_{EE}/R_{EE}) * L * \Delta T * Hours)/(\eta DHW_{Elec} * 3{,}412)$$

Where:

C_{Base} = Circumference (ft) of uninsulated pipe
= Diameter (in) * π/12
= Actual or if unknown, assume 0.196 ft for a pipe with a 0.75 inch diameter

R_{Base} = Thermal resistance coefficient (hr-°F-ft^2)/Btu) of uninsulated pipe
= 1.0[201]

C_{EE} = Circumference (ft) of insulated pipe
= Diameter (in) * π/12
= Actual or if unknown, assume 0.524 ft for a 0.46 in diameter pipe insulated with 3/4 in, R-4 wrap ((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 or if unknown, assume 5.0 for R-4 wrap or 7.0 for R-6 wrap

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

198 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).
199 Average cost of R-5 pipe wrap installation from the National Renewable Energy Laboratory's National Residential Efficiency Measures Database. http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=323
200 Cost based on RS Means 2018 data
201 "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets," Navigant, April 2009.

= Actual or if unknown, assume 6 ft
ΔT = Average temperature difference (°F) between supplied water and outside air
= Actual or if unknown, assume 60°F[202]
Hours = Hours per year
= 8,766
ηDHW_{Elec} = Recovery efficiency of electric hot water heater
= Actual or if unknown, assume 0.98[203]
3,412 = Conversion factor from Btu to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, as calculated above.
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:

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

Where:

ηDHW_{Gas} = Recovery efficiency of gas hot water heater
= 0.78[204]
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:

[202] Assumes 125°F water leaving the hot water tank and average basement temperature of 65°F.
[203] Electric water heater recovery efficiency from AHRI database: http://www.ahridirectory.org/ahridirectory/pages/home.aspx.
[204] 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%.

3.3.6 Thermostatic Restrictor Shower Valve

DESCRIPTION

The measure is the installation of a thermostatic restrictor shower valve in a single or multifamily household. This is a valve attached to a residential showerhead which restricts hot water flow through the showerhead once the water reaches a set point (generally 95F or lower).

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a thermostatic restrictor shower valve installed on a residential showerhead.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the residential showerhead without the restrictor valve installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years. [205]

DEEMED MEASURE COST

The incremental cost of the measure should be the actual program cost (including labor if applicable) or $30[206] plus $20 labor[207] if not available.

LOADSHAPE

Water Heating RES

COINCIDENCE FACTOR

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

[205] Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113 and measure life of lowflow showerhead.
[206] Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.
[207] Estimate for contractor installation time.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * EPG_electric * ISR

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%[208]

GPM_base_S = Flow rate of the base case showerhead, or actual if available

Program	GPM
Direct-install, device only	1.5[209]
New Construction or direct install of device and low flow showerhead	Rated or actual flow of program-installed showerhead
Retrofit or TOS	2.35[210]

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve
= 0.89 minutes[211]

Household = Average number of people per household

Household Unit Type[212]	Household
Single-Family - Deemed	2.67[213]
Multi-Family - Deemed	2.07[214]
Custom	Actual Occupancy or Number of Bedrooms[215]

SPCD = Showers Per Capita Per Day
= 0.66[216]

365.25 = Days per year, on average.

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

Household Type	SPH
Single-Family	2.05[217]
Multi-Family	1.4[218]
Custom	Actual

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

[209] Illinois Statewide Technical Reference Manual for Energy Efficiency Version 5.0. pp. 184. 2016. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Version_5.0_dated_February-11-2016_Final_Compiled_Volumes_1-4.pdf. Assumes low flow showerhead is included in direct installation.

[210] Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

[211] Average of the following sources: ShowerStart LLC survey; "Identifying, Quantifying and Reducing Behavioral Waste in the Shower: Exploring the Savings Potential of ShowerStart" City of San Diego Water Department survey; "Water Conservation Program: ShowerStart Pilot Project White Paper," and PG&E Work Paper PGECODHW113.

[212] If household type is unknown, as may be the case for TOS measures, then single family deemed value should be used.

[213] Missouri TRM 2017 - Low Flow Showerheads 3.3.2.

[214] Missouri TRM 2017 - Low Flow Showerheads 3.3.2.

[215] 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.

[216] DeOreo, William, P. Mayer, L. Martien, M. Hayden, A. Funk, M. Kramer-Duffield, and R. Davis (2011). "California Single Family Water Use Efficiency Study."

[217] Missouri TRM 2017 - Low Flow Showerheads 3.3.2.

[218] Missouri TRM 2017 - Low Flow Showerheads 3.3.2.

EPG_electric = Energy per gallon of hot water supplied by electric
= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)
= (8.33 * 1.0 * (105 – 61.3)) / (0.98 * 3412)
= 0.109 kWh/gal
8.33 = Specific weight of water (lbs/gallon)
1.0 = Heat capacity of water (btu/lb-°)
ShowerTemp = Assumed temperature of water
= 105F[219]
SupplyTemp = Assumed temperature of water entering house
= 61.3F[220]
RE_electric = Recovery efficiency of electric water heater
= 98%[221]
3412 = Converts Btu to kWh (btu/kWh)
ISR = In service rate of showerhead
= Dependent on program delivery method as listed in table below

Selection	ISR
Direct Install - Single Family	0.91
Direct Install – Multi Family	0.91[222]
Efficiency Kits	To be determined through evaluation

EXAMPLE

For example, a direct installed valve in a single-family home with electric DHW:

ΔkWh = 1.0 * (2.67 * 0.89 * 1.5 * 0.66 * 365.25 / 2.05) * 0.108 * 0.91
= 42 kWh

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/Hours * CF

Where:
ΔkWh = calculated value above
Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device
= ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25) * 0.712[223] / GPH
GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.
= 27.51
= 34.4 for SF direct install; 28.3 for MF direct install
= 30.3 for SF Retrofit and TOS; 24.8 for MF Retrofit and TOS
Water Heating RES

EXAMPLE

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

ΔkW = 85.3/34.4 * 0.0022
= 0.0055 kW

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219 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 5.0. 2016. pp 103. Available Online: http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Version_5.0_dated_February-11-2016_Final_Compiled_Volumes_1-4.pdf.
220 Ameren Missouri 2012 Technical Resource Manual. Appendix A. pp. 43. https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935658483.
221 Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx.
222 Based on Ameren Missouri Community Savers Evaluation.
223 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

Natural Gas Savings

ΔTherms = %FossilDHW * ((GPM_base_S * L_showerdevice)* Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

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

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[224]

EPG_gas = Energy per gallon of Hot water supplied by gas
= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)
= 0.00501 therm/gal for SF homes
= 0.00583 therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater
= 78% For SF homes[225]
= 67% For MF homes[226]

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

Other variables as defined above.

EXAMPLE

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

ΔTherms = 1.0 * ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98
= 3.7 therms

Water Impact Descriptions and Calculation

Δgallons = ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

EXAMPLE

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

Δgallons = ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98
= 730 gallons

Deemed O&M Cost Adjustment Calculation

N/A

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

[225] 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%.

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

Sources

Source ID	Reference
1	2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011.
2	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
3	1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999.
4	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
5	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
6	2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011.
7	2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.
8	2011, Lutz, Jim. "Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems," Energy Analysis Department Lawrence Berkeley National Laboratory, September 2011.
9	2008, Water Conservation Program: ShowerStart Pilot Project White Paper, City of San Diego, CA.
10	2012, Pacific Gas and Electric Company, Work Paper PGECODHW113, Low Flow Showerhead and Thermostatic Shower Restriction Valve, Revision # 4, August 2012.
11	2008, "Simply & Cost Effectively Reducing Shower Based Warm-Up Waste: Increasing Convenience & Conservation by Attaching ShowerStart to Existing Showerheads," ShowerStart LLC.
12	2014, New York State Record of Revision to the TRM, Case 07-M-0548, June 19, 2014.

Measure Code:

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.[227] 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.[228] 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; all thermostats controlling household heat should be programmable and 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[229] 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,[230] 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.[231]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat -- 10 years[232] -- based upon equipment life only.[233]

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[227] 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.

[228] 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."

[229] 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.

[230] 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.

[231] 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.

[232] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

[233] Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a number of savings studies that lasted a single year or less, the longer-term impacts should be assessed.

DEEMED MEASURE COST

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used. For retail, Bring Your Own Thermostat (BYOT) programs,[234] or other program types, actual costs are still preferable.[235] If actual costs are unknown, then the average incremental cost for the new installation measure is assumed to be $175.[236]

LOADSHAPE

Cooling RES

Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh^{237} = \Delta kWh_{heating} + \Delta kWh_{cooling}$$

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

$$\Delta kWh_{cool} = \%AC * ((EFLHcool * CapacityCool * 1/SEER)/1000) * CoolingReduction * Eff\_ISR$$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[238]

$HeatingConsumption_{Electric}$ = Estimate of annual household heating consumption for electrically heated single-family homes.[239]

Weather Basis (City based upon)	Elec_Heating_ Consumption (kWh)		
	Electric Resistance	Electric Heat Pump	Unknown Electric[240]
St Louis, MO	14,144	8,320	13,416

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

Household Type	HF
Single-Family	100%
Multi-Family	65%[241]
Actual	Custom[242]

[234] In contrast to program designs that utilize program-affiliated contractors or other trade ally partners that support customer participation through thermostat distribution, installation, and other services, BYOT programs enroll customers after the time of purchase through online rebate and program integration sign-ups.

[235] Actual costs include any one-time software integration, annual software maintenance, and/or individual device energy feature fees.

[236] 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 can be found on units readily available in the market. Prices are in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Add-on energy service costs, which may include one-time setup and/or annual per device costs, are not included in this assumption.

[237] 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.

[238] 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.

[239] Values in table are based on converting an 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, Navigant, August 1 2013) to an electric heat load (divide by 0.03413) to electric resistance and ASHP heat load (resistance load reduced by 15% to account for distribution losses that occur in furnace heating but not in electric resistance while ASHP heat is assumed to suffer from similar distribution losses) and then to electric consumption assuming efficiencies of 100% for resistance and 200% for HP (see 'Thermostat_FLH and Heat Load Calcs.xls'). The other weather basis values are calculated using climate normals HDD data with a base temp ratio of 60°F.

[240] Assumption that 12.5% of electrically heated homes in Missouri have heat pumps, based on 2009 Residential Energy Consumption Survey for Missouri.

[241] 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

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

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

Existing Thermostat Type	Heating_Reduction[243]
Manual	8.8%
Programmable	5.6%
Unknown (Blended)	7.4%

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication
= If programs are evaluated during program deployment then custom ISR assumptions should be applied. If in service rate is captured within the savings percentage, ISR should be 100%. If using default savings, use 100%.[244]

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%[245]

29.3 = kWh per therm

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

Thermostat control of air conditioning?	%AC
Yes	100%
No	0%
Unknown	Actual population data, or 91%[246]

$EFLH_{cool}$ = Equivalent full load hours of air conditioning:[247]

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

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

SEER = the cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh)
= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 13.[248]

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%[249]

[243] 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). 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.

[244] 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.

[245] 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.

[246] 91% of homes have central cooling in Missouri (based on 2009 Residential Energy Consumption Survey, see "RECS 2009 Air Conditioning_hc7.9.xls").

[247] Based on full load hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren Missouri territory, which suggests an appropriate EFLH of 869.The other weather basis values are calculated using the relative climate normals cooling degree day ratios (at 65F set point).

[248] Based on minimum federal standard: http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html.

[249] 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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[250]

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \%FossilHeat * HeatingConusmption_{Gas} * HF * HeatingReduction * Eff\_ISR$$

Where:

%FossilHeat = Percentage of heating savings assumed to be Natural Gas

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	65%[251]

$HeatingConsumption_{Gas}$
= Estimate of annual household heating consumption for gas heated single-family homes.[252]

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:

[250] 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

[251] 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.

[252] 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, 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.

3.4.2 Air Source Heat Pump Including Dual Fuel Heat Pumps

DESCRIPTION
An air source heat pump provides heating or cooling by moving heat between indoor and outdoor air. A dual fuel heat pump pairs an air source heat pump with a gas furnace. The air source heat pump provides heating in mild weather, and as temperature drop the heat pump shuts off and the furnace provides heating.

This measure characterizes:

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

b) 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 air 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 and the Baseline SEER is the actual SEER value of the unit replaced and if unknown use assumptions in the variable list below ($SEER_{exist}$ and $HSPF_{exist}$). 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.

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 based on the current federal standard efficiency level as of January 1, 2015; 14 SEER and 8.2HSPF, when replacing an existing air source heat pump; and 13 SEER and 3.41 HSPF when replacing a central air conditioner and electric resistance heating.

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.[253]
Remaining life of existing ASHP/CAC equipment is assumed to be 6 years[254] and 18 years for electric resistance.

DEEMED MEASURE COST
Dual Fuel Heat Pump:

Efficiency (EER)	Cost (including labor) per measure
DFHP - SEER 19 MF heat pump base	2936.6
DFHP - SEER 20 MF heat pump base	3176.6
DFHP - SEER 21 MF heat pump base	3626.6

Air Source Heat Pump:

TOS: The incremental capital cost for this measure is dependent on the efficiency and capacity of the new unit. Note these costs are per ton of unit capacity:

[253] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf.
[254] Assumed to be one third of effective useful life.

Efficiency (SEER)	Incremental Cost per Ton of Capacity ($/ton)	Source
SEER 15	$303.00	IL TRM V6.0
SEER 16	$392.70	RS Means 2018 data
SEER 17	$580.00	RS Means 2018 data
SEER 18	$713.33	RS Means 2018 data
SEER 19	$813.33	RS Means 2018 Data
SEER 20	$1,160.00	RS Means 2018 Data
SEER 21	$1,160.00	SEER 20 value used

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

Efficiency (SEER)	Full Retrofit Cost (including labor) per Ton of Capacity ($/ton)	Source
SEER 15	$844.69	IL TRM V6.0
SEER 16	$934.39	RS Means 2018 data
SEER 17	$1,121.69	RS Means 2018 data
SEER 18	$1,255.02	RS Means 2018 data
SEER 19	$1,355.02	RS Means 2018 Data
SEER 20	$1,701.69	RS Means 2018 Data
SEER 21	$1,701.69	SEER 20 value used

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

LOADSHAPE
Cooling RES
Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
TOS:

$$\Delta kWh = ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{base} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{base} - 1/HSPF_{ee})) / 1000)$$

EREP:[255]

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

$$= ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{exist} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{exist} - 1/HSPF_{ee})) / 1000)$$

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

$$= ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{base} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{base} - 1/HSPF_{ee})) / 1000)$$

Where:

$EFLH_{cool}$ = Equivalent full load hours of air conditioning[256]:

[255] 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.

[256] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren Missouri' service territory, suggesting an appropriate EFLH of 869.The other weather basis values are calculated using the relative climate normals cooling degree day ratios (at 65F set point).

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)

$SEER_{exist}$ = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)
= Use actual SEER rating where it is possible to measure or reasonably estimate.

Existing Cooling System	$SEER_{exist}$[257]
Air Source Heat Pump	7.2
Central AC	6.8
No central cooling[258]	Let '$1/SEER_{exist}$' = 0

$SEER_{base}$ = Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)
= 14[259]

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

$EFLH_{heat}$ = Equivalent full load hours of heating:[260]

Weather Basis (City based upon)	$EFLH_{heat}$ (Hours)
St Louis, MO	2009 for ASHP and 1119 for DFHP

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

$HSPF_{exist}$ =Heating System Performance Factor of existing heating system (kBtu/kWh)
= Use actual HSPF rating where it is possible to measure or reasonably estimate. If not available use:

Existing Heating System	$HSPF_{exist}$
Air Source Heat Pump	5.44[261]
Electric Resistance	3.41[262]

$HSPF_{base}$ =Heating System Performance Factor of baseline Air Source Heat Pump (kBtu/kWh)
= 8.2[263]

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

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

CF = 0.0009474181

[257] 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 operations SEER represents degradation to 78.9% of nameplate. 78.9% of 8.6 SEER CAC nameplate gives an operational SEER of 6.8.

[258] 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.

[259] Based on minimum federal standard effective 1/1/2015: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

[260] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other weather basis values are calculated using the relative climate normals HDD data with a base temp ratio of 60°F.

[261] 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 PY3-PY4. This estimation methodology appears to provide a result within 10% of actual HSPF.

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

[263] Based on minimum federal standard effective 1/1/2015: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

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:
   http://www.resnet.us/standards/DRAFT_Chapter_8_July_22.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.[264]

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:

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

Where:

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

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

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

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	House to Duct Pressure	Subtraction Correction Factor
50	1.00	30	2.23
49	1.09	29	2.32
48	1.14	28	2.42
47	1.19	27	2.52
46	1.24	26	2.64
45	1.29	25	2.76
44	1.34	24	2.89
43	1.39	23	3.03
42	1.44	22	3.18
41	1.49	21	3.35
40	1.54	20	3.54
39	1.60	19	3.74
38	1.65	18	3.97
37	1.71	17	4.23
36	1.78	16	4.51
35	1.84	15	4.83
34	1.91	14	5.20
33	1.98	13	5.63
32	2.06	12	6.12
31	2.14	11	6.71

b. Calculate duct leakage reduction, convert to $CFM25_{DL,}$[265] and factor in Supply and Return Loss Factors:

$$Duct\ Leakage\ Reduction\ (\Delta CFM25_{\mathrm{DL}}) = (Pre\ CFM50_{DL} - Post\ CFM50_{DL}) * 0.64 * (SLF + RLF)$$

Where:

0.64 = Converts $CFM50_{DL}$ to $CFM25_{DL}$[266]

SLF = Supply Loss Factor[267]
= % leaks sealed located in Supply ducts * 1
Default = 0.5[268]

RLF = Return Loss Factor[269]
= % leaks sealed located in Return ducts * 0.5
Default = 0.25[270]

---

[265] 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions.

[266] 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).

[267] 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.

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

[269] 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.

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

c. Calculate electric savings

$$\Delta kWh = \Delta kWhCooling + \Delta kWhHeating$$

$$\Delta kWhCooling = \frac{\frac{\Delta CFM25_{DL}}{(CapacityCool/12000 * 400)} * EFLHcool * CapacityCool}{1000 * SEER}$$

$$\Delta kWhHeating_{Electric} = \frac{\frac{\Delta CFM25_{DL}}{(CapacityHeat/12000 * 400)} * EFLHheat * CapacityHeat}{COP * 3412}$$

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

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) [271]

EFLHcool = Equivalent Full Load Cooling Hours:[272]

Weather Basis (City based upon)	EFLHcool (Hours)
St Louis, MO	869

1000 = Converts Btu to kBtu

SEER = Efficiency in SEER of Air Conditioning equipment
= Actual - If not available, use:[273]

Equipment Type	Age of Equipment	SEER Estimate
Central AC	Before 2006	10
	After 2006	13
Heat Pump	Before 2006	10
	2006-2014	13
	2015 on	14

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

EFLHheat = Equivalent Full Load Heating Hours:[274]

Weather Basis (City based upon)	EFLHheat (Hours)
St Louis, MO	2009

COP = Efficiency in COP of Heating equipment
= Actual - If not available, use:[275]

[271] This conversion is an industry rule of thumb. E.g., see http://www.hvacsalesandsupply.com/Linked%20Documents/Tech%20Tips/61-Why%20400%20CFM%20per%20ton.pdf.

[272] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren territory suggesting an appropriate EFLH of 869.The other weather basis values are calculated using the relative climate normals cooling degree day ratios (at 65F set point).

[273] 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.

[274] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other climate region values are calculated using the relative climate normals HDD data with a base temp ratio of 60°F.

[275] These default system efficiencies are based on the applicable minimum federal standards. In 2006 the federal standard for heat pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

System Type	Age of Equipment	HSPF Estimate	COP (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

3412 = Converts Btu to kWh
ΔTherms = Therm savings as calculated in Natural Gas Savings
F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[276]
29.3 = kWh per therm

Methodology 2: Duct Blaster Testing

$$\Delta kWh = \Delta kWhCooling + \Delta kWhHeating$$

$$\Delta kWhCooling = \frac{\frac{Pre\_CFM25 - Post\_CFM25}{CapacityCool/12000 * 400} * EFLHcool * CapacityCool}{1000 * SEER}$$

$$\Delta kWhHeating_{Electric} = \frac{\frac{Pre\_CFM25 - Post\_CFM25}{CapacityCool/12000 * 400} * EFLHheat * CapacityHeat}{COP * 3412}$$

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

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[277]

$$\Delta kWh = \Delta kWhcooling + \Delta kWhHeating$$

$$\Delta kWhcooling = CoolSavingsPerUnit * Duct_{Length}$$

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

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

Where:

CoolSavingsPerUnit = Annual cooling savings per linear foot of duct

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

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

HeatSavingsPerUnit = Annual heating savings per linear foot of duct

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

[276] 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.

[277] 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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW \quad = \Delta kWh_{cooling} * CF$$

Where:

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

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[278]

NATURAL GAS SAVINGS

For homes with Natural Gas Heating:

Methodology 1: Modified Blower Door Subtraction

$$\Delta Therm = \frac{\frac{\Delta CFM25_{DL}}{CapacityHeat * 0.0136} * EFLHheat * CapacityHeat * \frac{\eta Equipment}{\eta System}}{100{,}000}$$

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)[279]

ηEquipment = Heating Equipment Efficiency
= Actual[280] - If not available, use 83.5%[281]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[282]
= Actual - If not available use 71.0%[283]

100,000 = Converts Btu to therms

Methodology 2: Duct Blaster Testing

$$\Delta Therms = \frac{\frac{Pre\_CFM25 - Post\_CFM25}{CapacityHeat * 0.0136} * EFLHgasheat * CapacityHeat * \frac{\eta Equipment}{\eta System}}{100{,}000}$$

Where:

All variables as provided above

Methodology 3: Deemed Savings[284]

$$\Delta Therms = HeatSavingsPerUnit * Duct_{Length}$$

[278] 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf."

[279] 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 http://contractingbusiness.com/enewsletters/cb_imp_43580/). 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.

[280] 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.

[281] 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.

[282] 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 - (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) - or by performing duct blaster testing.

[283] Estimated as follows: 0.835 * (1-0.15) = 0.710.

[284] 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.

Where:

HeatSavingsPerUnit = Annual heating savings per linear foot of duct

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

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

3.4.4 Ductless Air Source Heat Pump

DESCRIPTION

This measure is designed to calculate electric savings from retrofitting existing electric HVAC systems with ductless mini-split heat pumps (DMSHPs). DMSHPs save energy in heating mode because they provide heat more efficiently than electric resistance heat and central ASHP systems. Additionally, DMSHPs use less fan energy to move heat and don't incur heat loss through a duct distribution system. Often DMSHPs are installed in addition to (do not replace) existing heating equipment because at extreme cold conditions many DMSHPs cannot provide enough heating capacity, although cold-climate heat pumps can continue to perform at sub-zero temperatures.

For cooling, the proposed savings calculations are aligned with those of typical replacement systems. DMSHPs save energy in cooling mode because they provide cooling capacity more efficiently than other types of unitary cooling equipment. A DMSHP installed in a home with a central ASHP system will save energy by offsetting some of the cooling energy of the ASHP. In order for this measure to apply, the control strategy for the heat pump is assumed to be chosen to maximize savings per installer recommendation.[285]

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

In order for this characterization to apply, the new equipment must be a high-efficiency, variable-capacity (typically "inverter-driven" DC motor) ductless heat pump system that exceeds the program minimum efficiency requirements.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, baseline equipment must include a permanent electric resistance heating source or a ducted air-source heat pump. 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years.[286]

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[285] 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.

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

DEEMED MEASURE COST

The incremental cost for this measure is provided below:

Measure	Incremental Cost ($/ 1.5 ton)	Source
Ductless AC - ER1 SF	$2,108	Ameren Missouri MEEIA 2016-18 TRM effective January 1, 2018
Ductless AC - Replace on fail SF	$1,545	RS Means 2018 data
Ductless ASHP - Replace on fail SF NC	$888	Ameren Missouri MEEIA 2016-18 TRM effective January 1, 2018
Ductless ASHP - Replace on fail SF ROF	$888.	Ameren Missouri MEEIA 2016-18 TRM effective January 1, 2018
Ductless ASHP Replace Electric Resistance ER1 SF	$2,108	Ameren Missouri MEEIA 2016-18 TRM effective January 1, 2018
Ductless ASHP Replace Electric Resistance ROF	$1,051	Ameren Missouri MEEIA 2016-18 TRM effective January 1, 2018
Ductless ASHP ER1 SF	$1,982	Ameren Missouri MEEIA 2016-18 TRM effective January 1, 2018
Ductless AC - ER1 MF	$1,413	RS Means 2018 data
Ductless AC - Replace on fail MF	$978.50	RS Means 2018 data
Ductless ASHP - Replace on fail MF NC	$705	RS Means 2018 data
Ductless ASHP - Replace on fail MF ROF	$705	RS Means 2018 data
Ductless ASHP Replace Electric Resistance ER1 MF	$1,590	RS Means 2018 data
Ductless ASHP Replace Electric Resistance ROF MF	$705	RS Means 2018 data
Ductless ASHP ER1 MF	$1,440	RS Means 2018 data

LOADSHAPE

Cooling RES

Heating RES

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings

$$\Delta kWh = \Delta kWh_{heat} + \Delta kWh_{cool}$$

$$\Delta kWh_{heat} = (Capacity_{heat} * EFLH_{heat} * (1/HSPF_{exist} - 1/HSPF_{ee})) / 1000$$

$$\Delta kWh_{cool} = (Capacity_{cool} * EFLH_{cool} * (1/SEER_{exist} - 1/SEER_{ee})) / 1000$$

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 (City based upon)	$EFLH_{heat}$[287]
St Louis	1,496

[287] Ameren Missouri Heating and Cooling Evaluation - Program Year 2016.

$HSPF_{exist}$ = HSPF rating of existing equipment (kbtu/kwh)

Existing Equipment Type	$HSPF_{exist}$
Electric resistance heating	3.412[288]
Air Source Heat Pump	5.44[289]

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

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr.[290]
= Actual installed

$SEER_{ee}$ = SEER rating of new equipment (kbtu/kwh)
= Actual installed[291]

$SEER_{exist}$ = SEER rating of existing equipment (kbtu/kwh)

= Use actual value. If unknown, see table below

Existing Cooling System	$SEER_{exist}$[292]
Air Source Heat Pump	7.2
Central AC	6.8
Room AC	6.3[293]
No existing cooling[294]	Let '1/SEER_exist' = 0

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. See table below[295] **Weather Basis**	$EFLH_{cool}$
St Louis	869

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = 0.0009474181

NATURAL GAS SAVINGS

N/A

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

[289] 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 PY3-PY4. This estimation methodology appears to provide a result within 10% of actual HSPF.

[290] 1 Ton = 12 kBtu/hr.

[291] 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).

[292] 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 operations SEER represents degradation to 78.9% of nameplate. 78.9% of 8.6 SEER CAC nameplate gives an operational SEER of 6.8, 78.9% of 8.0 SEER RAC nameplate gives an operational SEER of 6.3.

[293] 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.

[294] 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.

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

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; all thermostats controlling household heat should be programmable and 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: RF, and DI.

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention.

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.[296]

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.[297]

LOADSHAPE

Cooling RES

Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For central air conditioners and air source heat pumps:

$$\Delta kWhcool = EFLHcool * Capacitycooling * \left(\frac{1}{SEER}\right) * SBdegrees * SF * EF/1000$$

For air source heat pumps there are additional heating savings:

$$\Delta kWhheat = EFLHheat * Capacityheating * \left(\frac{1}{HSPF}\right) * SBdegrees * SF * EF/1000$$

Where:

$EFLHcool$ = Full load cooling hours

[296] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007. 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.

[297] 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.

EFLHcool_stat = Full load cooling hours with setback schedule

CapacityCooling = Cooling capacity of system in BTU/hr (1 ton = 12,000 BTU/hr)

SEERCAC = SEER efficiency of central air conditioner

SEERASHP = SEER efficiency of air source heat pump

HSPFASHP = Heating Season Performance Factor of system

FLHheat = Full load heating hours

FLHheat = Full load heating hours with setback schedule

CapacityHeating = Heating capacity of system in BTU/hr (1 ton = 12,000 BTU/hr)

SBdegrees = weighted sum of setback degrees to comfort temperature

SF = Savings factors from ENERGY STAR® calculator
EF = Efficiency ratio from Cadmus metering study

Parameter	*Value*	*Source*
FLH_{cool}	1,215 (St. Louis region)	ENERGY STAR air-source heat pump calculator[1]
$Capacity_{Cooling}$	Per unit serviced	PY2016 program data
$SEER_{CAC}$	10	IL-TRM (Based on minimum federal standards between 1992 and 2006.)[2]
$SEER_{ASHP}$	10	IL-TRM (Based on minimum federal standards between 1992 and 2006.)[2]
$HSPF_{ASHP}$	6.8	IL-TRM (Based on minimum federal standards between 1992 and 2006.)[2]
FLH_{heat}	2,009 (St. Louis region)	ENERGY STAR air-source heat pump calculator
$Capacity_{Heating}$	Per unit serviced	PY2016 program data
SBdegrees	-8F heat,4 to 7 cool	ENERGY STAR Setpoints
SF	3%/degree heat, 6%/degree cool	ENERGY STAR Calculator
EF	13% heat, 18% cool	Cadmus metering study[3]

1. https://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls
2. Illinois Statewide Technical Reference Manual v. 5.0 http://www.ilsag.info/il_trm_version_5.html
3. Ameren Missouri Low Income and Process Evaluation: program Year 2014. p. 31

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:
CF = 0.0009474181
N/A due to no savings from cooling during the summer peak period.

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%[298]

$HeatingConsumption_{Gas}$ = Estimate of annual household heating consumption for gas heated single-family homes.[299]

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:

[298] 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.

[299] 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, 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.

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.[300]

DEEMED MEASURE COST

As a RF measure, actual costs should be used. If unavailable, the measure cost should be assumed to be $175.[301] The table below identifies more specific costs for varying services (lower three.

Tune- up Service for HP or AC	Incremental Cost ($)	
General Tune-Up (no charge or coil clean)	$70.00	
Tune-up / refrigerant charge	$81.00	$175.00
Tune-up / Indoor Coil (Evaporator) Cleaning	$63.00	
Tune-up / Outdoor Coil (Condenser) Cleaning	$31.00	

LOADSHAPE

Cooling RES
Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh_{Central\ AC} = ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{test\text{-}in} - 1/SEER_{test\text{-}out})) / 1000)$$

$$\Delta kWh_{ASHP} = ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{test\text{-}in} - 1/SEER_{test\text{-}out})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{test\text{-}in} - 1/HSFP_{test\text{-}out})) / 1000)$$

Where:

$EFLH_{cool}$ = Equivalent full load hours of air conditioning
= dependent on location:[302]

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)

---

[300] Sourced from DEER Database Technology and Measure Cost Data.

[301] 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.

[302] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren territory suggesting an appropriate EFLH of 869.The other weather basis values are calculated using the relative climate normals cooling degree day ratios (at 65F set point).

$SEER_{test-in}$ = 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:[303]
$EER = (-0.02 * SEER^2) + (1.12 * SEER)$
When unknown,[304] assume SEER = 11.9

$SEER_{test-out}$ = 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:[305]

$EER = (-0.02 * SEER^2) + (1.12 * SEER)$

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

Measure	% Improvement
Refrigerant charge adjustment	28.4%
Condenser Cleaning Only	7.9%
Indoor coil cleaning	3.8%
General tune-up	5.6%

$EFLH_{heat}$ = Equivalent full load hours of heating:[306]

Weather Basis (City based upon)	$EFLH_{heat}$ (Hours)
St Louis, MO	2009

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

$HSPF_{test-in}$ Pump before tuning (kBtu/kWh)
= Use actual HSPF rating where it is possible to measure or reasonably estimate. If not available, assume[307] HSPF = 6.3.

$HSPF_{test-out}$ =Heating System Performance Factor of existing Air Source Heat Pump after tuning (kBtu/kWh)
= Use actual HSPF rating where it is possible to measure or reasonably estimate. If not available, assume[308] HSPF = 6.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = 0.0009474181

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

303 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.

304 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."

305 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.

306 Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other weather basis values are calculated using the Climate Normals Heating Degree Day ratios (at 60F set point).

307 Based on evaluation results outlined in "Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015."

308 Assumes the efficiency improvement is the same in heating mode as was realized in cooling mode. Based on the improvement reported in "Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015."

MEASURE CODE:

3.4.7 Blower Motor

DESCRIPTION

A new furnace with a brushless permanent magnet (BPM) blower motor is installed instead of a new furnace with a lower efficiency motor. This measure characterizes only the electric savings associated with the fan and could be coupled with gas savings associated with a more efficient furnace. Savings decrease sharply with static pressure so duct improvements, and clean, low pressure drop filters can maximize savings. Savings improve when the blower is used for cooling as well and when it is used for continuous ventilation, but only if the non-BPM motor would have been used for continuous ventilation too. If the resident runs the BPM blower continuously because it is a more efficient motor and would not run a non-BPM 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.

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 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[309]

DEEMED MEASURE COST

The capital cost for this measure is assumed to be:

Incremental Cost ($)	
$97[310]	Time of Sale
$475[311]	Early Replacement

LOADSHAPE

HVAC RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh_{Heating\ Mode} = (1 - \%\ with\ New\ ASHP) \times \left(400\frac{kWh}{year} \times \frac{Heating\ EFLH}{Wisconsin\ Heating\ EFLH}\right)$$

$$\Delta kWh_{Cooling\ Mode} = (1 - \%\ with\ New\ Central\ Cooling) \times \left(70\frac{kWh}{year} \times \frac{Cooling\ EFLH}{Wisconsin\ CoolingEFLH}\right)$$

$$\Delta kWh_{Auto\ Circulation} = 25\frac{kWh}{year} \times \frac{CoolingEFLH}{Wisconsin\ CoolingEFLH} + 2960\frac{kWh}{year} \times 10\% - 30\frac{kWh}{year}$$

$$\Delta kWh_{Continous\ Circulation} = 25\frac{kWh}{year} \times \frac{CoolingEFLH}{Wisconsin\ CoolingEFLH} + 2960\frac{kWh}{year} - 30\frac{kWh}{year}$$

[309] Consistent with assumed life of a new gas furnace. Table 8.3.3 The technical support documents for federal residential appliance standards: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf.

[310] Adapted from Tables 8.2.3 and 8.2.13 in http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/hvac_ch_08_lcc_2011-06-24.pdf.

[311] Minnesota TRM, https://www.energy.gov/sites/prod/files/2014/02/f7/case_study_variablespeed_furnacemotor.pdf.

Where:

Parameter	Value
Wisconsin Cooling Savings kWh/year	70.00
Cooling Savings All Systems	25.00
Wisconsin Cooling EFLH	542.50
Wisconsin Heating Savings kWh/year	400.00
Wisconsin Heating EFLH	2,545.25
Wisconsin Circulation Savings kWh/year	2,960.00
% of Circulation Used	10%
Standby losses	30
Saint Louis Heating EFLH	2,009.00
Saint Louis Cooling EFLH	1,215.00
% with New Central Cooling	0.97
% with New ASHP	0.16

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

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

NATURAL GAS SAVINGS

Δtherms[312] = - Heating Savings * 0.03412/ AFUE

Where:

0.03412 = Converts kWh to therms

AFUE = Efficiency of the Furnace
= Actual. If unknown assume 95%[313] if in new furnace or 64.4 AFUE%[314] 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:

[312] 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.

[313] Minimum efficiency rating from ENERGY STAR® Furnace Specification v4.0, effective February 1, 2013.

[314] Average nameplate efficiencies of all early replacement qualifying equipment in Ameren IL PY3-PY4.

3.4.8 Central Air Conditioner

DESCRIPTION
This measure characterizes:

a) 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.

b) EREP:
Early Replacement determination will be defined by program requirements. All other conditions will be considered TOS.
The baseline SEER of the existing central air conditioning unit replaced:

- If the SEER of the existing unit is known and, the baseline SEER is the actual SEER value of the unit replaced. If the SEER of the existing unit is unknown, use assumptions in variable list below (SEER_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; 15 SEER and 12 EER.

DEFINITION OF BASELINE EQUIPMENT
The baseline for the TOS measure is based on the current federal standard efficiency level: 13 SEER and 11 EER.
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[315] for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 18 years.[316]
Remaining life of existing equipment is assumed to be 6 years.[317]

DEEMED MEASURE COST
TOS: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below:

Efficiency Level	ROF Cost per Ton	Early Replacement Cost per Ton	Source
SEER 14	$0.00	$212.38	IL TRM 6.0
SEER 15	$108	$320.38	IL TRM 6.0
SEER 16	$221	$433.38	IL TRM 6.0
SEER 17	$404	$616.38	Based on RS Means 2018 data.
SEER 18	$620	$832.38	IL TRM 6.0
SEER 19	$715	$927.38	DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)
SEER 20	$834	$1,046.38	
SEER 21	$908	$1,120.38	
Average	$530	$742.38	

[315] Baseline SEER and EER should be updated when new minimum federal standards become effective.
[316] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf.
The "lifespan" of a central air conditioner is about 15 to 20 years (US DOE: http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12440).
[317] Assumed to be one third of effective useful life.

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 $3,413.[318]

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $3,140.[319] This cost should be discounted to present value using the utilities' discount rate.

LOADSHAPE

Cooling RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

ΔkWH = (FLHcool * Btu/hr * (1/SEERbase - 1/SEERee))/1000

Early replacement:[320]

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

=((FLHcool * Capacity * (1/SEERexist - 1/SEERee))/1000);

ΔkWH for remaining measure life (next 12 years):

= ((FLHcool * Capacity * (1/SEERbase - 1/SEERee))/1000)

Where:

FLHcool = Full load cooling hours:[321]

Weather Basis (City based upon)	EFLHcool (Hours)
St Louis, MO	869

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[322]

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

= 13[323]

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

= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 10.0.[324]

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

= Actual installed or 14.5 if unknown

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh* CF

Where:

CF = 0.0009474181

318 Based on 3 ton initial cost estimate for an ENERGY STAR® unit from ENERGY STAR® central AC calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls).

319 Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR® central AC calculator, $2,857, and applying inflation rate of 1.91% (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). While baselines are likely to shift in the future, there is currently no good indication of what the cost of a new baseline unit will be in 6 years. In the absence of this information, assuming a constant federal baseline cost is within the range of error for this prescriptive measure.

320 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).

321 Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren territory suggesting an appropriate EFLH of 869.The other weather basis values are calculated using the relative climate normals cooling degree day ratios (at 65F set point).

322 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.

323 Based on minimum federal standard; http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html.

324 Estimate based on Department of Energy standard between 1992 and 2006. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then that should be used.

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

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[325] for a filter replacement and 14 years 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,[326] 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

$$kWh\ Heating\ Savings = kW_{motor} * FLH_{heat} * EI$$

$$kWh\ Cooling\ Savings = kW_{motor} * FLH_{cool} * EI$$

325 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.

326 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
KW (motor)	Average motor full load electric demand (kW)	0.5
EFLH (heat)	Equivalent Full Load Hours (EFLH) Heating (hours/year)	1496
EFLH (cool)	Equivalent Full Load Hours (EFLH) Cooling (hours/year)	869
EI	Efficiency Improvement (%)	15%
Utility Adjustment	% Homes in Service Territory	86%
ISR	Installation Rate	47%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = 0.0004660805

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:

> TOS: the purchase and installation of a new efficient PTAC or PTHP.
>
> EREP: the early removal of an existing PTAC or PTHP from service, prior to its natural end of life, and replacement with a new efficient PTAC or PTHP unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life. 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.[327]
Remaining life of existing equipment is assumed to be 5 years.[328]

DEEMED MEASURE COST

TOS: The incremental capital cost for this equipment is estimated to be $84/ton.[329]
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.[330]
The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton.[331] This cost should be discounted to present value using the utilities' discount rate.

LOADSHAPE

Cooling RES
Heating RES

[327] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
[328] Standard assumption of one third of effective useful life.
[329] DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation.
[330] Based on DCEO – IL PHA Efficient Living Program data.
[331] Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Time of sale:

$\Delta kWh = ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{base} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{base} - 1/HSFP_{ee})) / 1000)$

Early replacement:[332]

ΔkWH for remaining life of existing unit:

$= ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{exist} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{exist} - 1/HSFP_{ee})) / 1000)$

ΔkWH for remaining measure life:

$= ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{base} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{base} - 1/HSFP_{ee})) / 1000)$

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 (City based upon)	$EFLH_{heat}$[333]
St Louis	1,040

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

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

Equipment Type	$HSPF_{base}$ (manufacture date prior to 1/2/2017)	$HSPF_{base}$ (manufacture date after to 1/1/2017)
PTAC	7.7	8.0
PTHP	7.7	8.0

$HSPF_{exist}$ = Actual HSPF rating of existing equipment (kbtu/kwh). If unknown, assume:

Existing Equipment Type	$HSPF_{exist}$
Electric resistance heating (PTAC)	3.412[334]
PTHP	5.44[335]

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr.[336]
= Actual installed

$SEER_{ee}$ = SEER rating of new equipment (kbtu/kwh)
= Actual installed[337]

$SEER_{base}$ = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh)

Equipment Type	$SEER_{base}$ (manufacture date prior to 1/2/2017)	$SEER_{base}$ (manufacture date after to 1/1/2017)
PTAC	13.0	14.0
PTHP	13.0	14.0

[332] 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).

[333] 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.

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

[335] 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 PY3-PY4. This estimation methodology appears to provide a result within 10% of actual HSPF.

[336] 1 Ton = 12 kBtu/hr.

[337] 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).

$SEER_{exist}$ = Actual SEER rating of existing equipment (kbtu/kwh). If unknown, assume:

Existing Cooling System	$SEER_{exist}$[338]
PTHP	7.2
PTAC	6.8

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling.

= Custom input if program or regional evaluation results are available, otherwise, per the following table.[339]

Weather Basis (City based upon)	$EFLH_{cool}$
St Louis	617

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

$\Delta kW = \Delta kWhcooling * CF$

CF = 0.0009474181

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[338] 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 operations SEER represents degradation to 78.9% of nameplate. 78.9% of 8.6 SEER CAC nameplate gives an operational SEER of 6.8.

[339] 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.

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:[340]

<table>
<tr><th>Product Class (Btu/H)</th><th>Federal Standard CEERbase, with louvered sides, without reverse cycle[341]</th><th>Federal Standard CEERbase, without louvered sides, without reverse cycle</th><th>ENERGY STAR® CEERee, with louvered sides</th><th>ENERGY STAR® CEERee, without louvered sides</th></tr>
<tr><td>< 8,000</td><td>11.0</td><td>10.0</td><td>11.5</td><td>10.5</td></tr>
<tr><td>8,000 to 10,999</td><td rowspan="2">10.9</td><td>9.6</td><td rowspan="2">11.4</td><td>10.1</td></tr>
<tr><td>11,000 to 13,999</td><td>9.5</td><td>10.0</td></tr>
<tr><td>14,000 to 19,999</td><td>10.7</td><td>9.3</td><td>11.2</td><td>9.7</td></tr>
<tr><td>20,000 to 24,999</td><td>9.4</td><td rowspan="3">9.4</td><td rowspan="2">9.8</td><td rowspan="3">9.8</td></tr>
<tr><td>25,000-27,999</td><td rowspan="2">9.0</td></tr>
<tr><td>>=28,000</td><td>9.5</td></tr>
</table>

Casement	Federal Standard CEERbase	ENERGY STAR® CEERee
Casement-only	9.5	10.0
Casement-slider	10.4	10.8

Reverse Cycle - Product Class (Btu/H)	Federal Standard CEERbase, with louvered sides	Federal Standard CEERbase, without louvered sides[342]	ENERGY STAR® CEERee, with louvered sides[343]	ENERGY STAR® CEERee, without louvered sides
< 14,000	N/A	9.3	N/A	9.7
>= 14,000	N/A	8.7	N/A	9.1
< 20,000	9.8	N/A	10.3	N/A
>= 20,000	9.3	N/A	9.7	N/A

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

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

The baseline assumption is a new room air conditioning unit that meets the current minimum federal efficiency standards presented above.

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[340] 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/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf.

[341] Federal standard air conditioner baselines. https://ees.lbl.gov/product/room-air-conditioners.

[342] Federal standard air conditioner baselines. https://ees.lbl.gov/product/room-air-conditioners.

[343] EnergyStar® version 4.0 Room Air Conditioner Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air% 20Conditioners%20Program%20Requirements.pdf.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The measure life is assumed to be 9 years.[344]

DEEMED MEASURE COST
The incremental cost for this measure is assumed to be $20 for an ENERGY STAR® unit.[345]

LOADSHAPE
Cooling RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{(FLH_{RoomAC} * Btu/H * \left(\frac{1}{CEERbase} - \frac{1}{CEERee}\right)}{1000}$$

Where:

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

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

Btu/H = Size of unit
= Actual. If unknown assume 8500 Btu/hr [346]

CEERbase = Efficiency of baseline unit
= As provided in tables above

CEERee = Efficiency of ENERGY STAR® unit
= Actual. If unknown assume minimum qualifying standard as provided in tables above

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.0009474181[347]

NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

[344] ENERGY STAR® Room Air Conditioner Savings Calculator: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=AC.
[345] Cost from RS Means 2018.
[346] Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.
[347] Based on Ameren Missouri 2016 loadshape 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:

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.

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 and the baseline SEER is the actual SEER value of the unit replaced and if unknown use assumptions in the variable list below ($SEER_{exist}$ and $HSPF_{exist}$). 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: 3.3 COP and 14.1 EER when replacing an existing ground source heat pump, 14 SEER and 8.2HSPF when replacing an existing air source heat pump, and 13 SEER and 3.41 HSPF when replacing a central air conditioner and electric resistance heating.
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.
For early replacement, the remaining life of existing equipment is assumed to be 6 years for GSHP, ASHP and CAC and 18 years for electric resistance.

DEEMED MEASURE COST
TOS: The incremental capital cost for this measure is dependent on the efficiency and capacity of the new unit.[348]

Efficiency (EER)	Cost (including labor) per measure
GSHP - EER 23 - replace electric furnace / CAC	$4,717
GSHP EER 23 Replace at Fail GSHP	$3,200

EREP: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume the following (note these costs are per ton of unit capacity):[349]

Efficiency (EER)	Cost (including labor) per measure
GSHP - EER 23 - replace electric furnace / CAC Early Replacement	$5,250
GSHP EER 23	$4,859

348 Cost based upon Ameren Missouri MEEIA 2016-18 TRM effective January 1, 2018.
349 Cost based upon Ameren Missouri MEEIA 2016-18 TRM effective January 1, 2018.

LOADSHAPE

Cooling RES

Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

TOS:

$$\Delta kWh = ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{base} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{base} - 1/HSPF_{ee})) / 1000)$$

EREP:[350]

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

$$= ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{exist} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{exist} - 1/HSPF_{ee})) / 1000)$$

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

$$= ((EFLH_{cool} * Capacity_{cool} * (1/SEER_{base} - 1/SEER_{ee})) / 1000) + ((EFLH_{heat} * Capacity_{heat} * (1/HSPF_{base} - 1/HSPF_{ee})) / 1000)$$

Where:

$EFLH_{cool}$ = Equivalent full load hours of air conditioning:[351]

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)

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

= Use actual SEER rating where it is possible to measure or reasonably estimate.

Existing Cooling System	$SEER_{exist}$[352]
Air Source Heat Pump	7.2
Central AC	6.8
No central cooling[353]	Let ‘$1/SEER_{exist}$’ = 0

$SEER_{base}$ = Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)

= 14[354]

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

= Actual

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

= Dependent on location:[355]

Weather Basis (City based upon)	$EFLH_{heat}$ (Hours)
St Louis, MO	2009

[350] 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).

[351] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren territory suggesting an appropriate EFLH of 869.The other climate region values are calculated using the relative climate normals cooling degree day ratios (at 65F set point).

[352] 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 operations SEER represents degradation to 78.9% of nameplate. 78.9% of 8.6 SEER CAC nameplate gives an operational SEER of 6.8.

[353] 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.

[354] Based on minimum federal standard effective 1/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

[355] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other weather basis values are calculated using the relative climate normals HDD data with a base temp ratio of 60°F.

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

$HSPF_{exist}$ =Heating System Performance Factor of existing heating system (kBtu/kWh)
= Use actual HSPF rating where it is possible to measure or reasonably estimate. If not available use:

Existing Heating System	$HSPF_{exist}$
Air Source Heat Pump	5.44[356]
Electric Resistance	3.41[357]

$HSPF_{base}$ =Heating System Performance Factor of baseline Air Source Heat Pump (kBtu/kWh)
= 8.2[358]

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

TOS:

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

CF = 0.0009474181

[356] 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 PY3-PY4. This estimation methodology appears to provide a result within 10% of actual HSPF.

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

[358] Based on minimum federal standard effective 1/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

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 requires 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. Therefore a midlife adjustment is provided.

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 (https://www.energystar.gov/sites/default/files/Luminaires%20V2%200%20Final.pdf).
Qualification could also be based on the Design Light Consortium's qualified product list.[359]

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an EISA-qualified halogen or incandescent lamp. From 2020, the baseline will change[360] based upon what is available in the market. Therefore a midlife adjustment is provided.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The rated life of omnidirectional LED lamps is assumed to be 20,000 hours.[361] This would imply a lifetime of 27 years for residential interior lighting and 15.2 years for residential exterior lighting. However, all installations are capped at 19 years.[362]

DEEMED MEASURE COST

While LEDs may have a higher upfront cost than a halogen or CFL, the incremental cost for LEDs in an upstream lighting program is assumed to be zero because the net present value of the costs to replace the halogen or CFL multiple times over the life of the LED is greater than the upfront cost of the LED. The incentive in this case is not designed to reduce the incremental cost over the lifetime of the measure. Instead the incentive is designed to reduce the initial upfront cost that may have been a barrier to the customer choosing the efficient lighting option. In the case of direct install programs or lighting included in efficient kits, the actual cost of the measure should be used.

LOADSHAPE

Lighting RES
Lighting BUS

[359] https://www.designlights.org/QPL.
[360] A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL.
[361] Version 1.1 of the ENERGY STAR® specification required omnidirectional bulbs have a rated life of 25,000 hours or more. Version 2.0 of the specification now only requires 15,000 hours. While the V2.0 is not effective until 1/2/2017, lamps may today be qualified with this updated rated life specification. In the absence of data suggesting an average – an assumed average rated life of 20,000 hours is used.
[362] Particularly in residential applications, lamps are susceptible to persistence issues such as removal, new fixtures, new occupants, etc. The measure life is capped at 19 years based on TAC agreement 1/19/2017.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh_{RES} = (Watt_{Base} - Watt_{EE}) * \%RES * ISR * (1 - LKG) * (Hours_{RES} * WHF_{RES}) / 1{,}000$$

$$\Delta kWh_{NRES} = (Watt_{Base} - Watt_{EE}) * (1 - \%RES) * ISR * (1 - LKG) * (Hours_{NRES} * WHF_{NRES}) / 1{,}000$$

Where:

$Watts_{Base}$ = Based on lumens of LED bulb installed.

$Watts_{EE}$ = Actual wattage of LED purchased / installed - If unknown, use default provided below:[363]

Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$ LED	Delta Watts
250	309	25	4.0	21
310	749	29	6.7	22.3
750	1,049	43	10.1	32.9
1,050	1,489	53	12.8	40.2
1,490	2,600	72	17.4	54.6
2,601	3,000	150	43.1	106.9
3,001	3,999	200	53.8	146.2
4,000	6,000	300	76.9	223.1

%RES = percentage of bulbs sold to residential customers

LKG = leakage rate (program bulbs installed outside Ameren Missouri's service area)

ISR = In Service Rate, the percentage of units rebated that are actually in service

Program	Discounted In Service Rate (ISR)
Retail (Time of Sale)	95.12%
Direct Install[364]	99%
Efficiency Kit (Single Family)[365]	92%
Efficiency Kit (Multi-Family)[366]	98%

$Hours_{RES}$ = Average hours of use per year

= Custom, or if unknown assume 728[367] for interior or 1314 for exterior, or 776 if location is not known.

$HoursN_{RES}$ = 3,613

$WHFe_{Heat}$ = 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[368]

[363] $Watts_{EE}$ defaults are based upon the average available ENERGY STAR® product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR® product currently available, $Watts_{EE}$ is based upon the ENERGY STAR® minimum luminous efficacy (55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts) for the mid-point of the lumen range. See calculation at "cerified-light-bulbs-2015-06-18.xlsx." These assumptions should be reviewed regularly to ensure they represent the available product.

[364] Ameren Missouri Home Energy Analysis Program Impact and Process Evaluation: Program Year 2015.

[365] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015.

[366] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015.

[368] Calculated using defaults: 1-((0.53/1.57) * 0.35) = 0.88.

Where:

HF = Heating Factor or percentage of light savings that must now be heated
= 53%[369] 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:[370]

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 and after	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.57[371]

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[372]

$WHFe_{Cool}$ = 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[373]
Building without cooling or exterior	1.0
Unknown	1.11[374]

Mid-Life Baseline Adjustment

During the lifetime of a standard omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes to a CFL equivalent beginning in 2020 (depending upon availability of halogen bulbs in the market), due to the EISA backstop provision (except for <310 and 2600+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift. This reduced annual savings will need to be incorporated in to cost-effectiveness screening calculations. The baseline adjustment also impacts the O&M schedule.

For example, for 43W equivalent LED lamp installed in 2016, the full savings (as calculated above in the Algorithm) should be claimed for the first four years and a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

[369] 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.

[370] 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.

[371] Calculation assumes 50% heat pump and 50% resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls." Average efficiency of heat pump is based on assumption 50% are units from before 2006 and 50% 2006-2014.

[372] 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.

[373] 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.

[374] 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 "HC7.9 Air Conditioning in Midwest Region.xls").

Lower Lumen Range	Upper Lumen Range	Mid Lumen Range	WattsEE	WattsBase before EISA 2020	Delta Watts before EISA 2020	WattsBase after EISA 2020[375]	Delta Watts after EISA 2020
250	309	280	4.0	25	21	25	21.0
310	749	530	6.7	29	22.3	9.4	2.7
750	1049	900	10.1	43	32.9	13.4	3.3
1050	1489	1270	12.8	53	40.2	18.9	6.1
1490	2600	2045	17.4	72	54.6	24.8	7.4
2,601	3,000	2,775	43.1	150	106.9	150	106.9
3,001	3,999	3,500	53.8	200	146.2	200	146.2
4,000	6,000	5,000	76.9	300	223.1	300	223.1

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0001492529 for residential bulbs and 0.0001899635 for nonresidential bulbs

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes:[376]

$$\Delta Therms = -\frac{\frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * HF * 0.03412}{\eta \text{Heat}} * \%\text{GasHeat}$$

Where:

HF = Heating Factor or percentage of light savings that must now be heated
= 53%[377] 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%[378]

%GasHeat = Percentage of heating savings assumed to be Natural Gas

Heating fuel	%GasHeat
Electric	0%
Natural Gas	100%
Unknown	65%[379]

MEASURE CODE:

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375 Calculated with EISA requirement of 45lumens/watt.

376 Negative value because this is an increase in heating consumption due to the efficient lighting.

377 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.

378 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 "HC6.9 Space Heating in Midwest Region.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.

379 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 requires 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

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 https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20AUG-2016.pdf). Qualification could also be based on the Design Light Consortium's qualified product list.[380]

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an EISA qualified halogen or incandescent. From 2020, the baseline will change based upon what is available in the market.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The ENERGY STAR® rated life requirement for directional bulbs is 25,000 and for decorative bulbs is 15,000 hours[381]. This would imply a lifetime of 34 years for residential interior directional and 21 years for residential interior decorative. However, all installations are capped at 19 years.[382]

DEEMED MEASURE COST

While LEDs may have a higher upfront cost than a halogen or CFL, the incremental cost for LEDs in an upstream lighting program is assumed to be zero because the net present value of the costs to replace the halogen or CFL multiple times over the life of the LED is greater than the upfront cost of the LED. Therefore, the incentive in this case is not designed to reduce the incremental cost over the lifetime of the measure. Instead the incentive is designed to reduce the initial upfront cost that may have been a barrier to the customer choosing the efficient lighting option. In the case of direct install programs or lighting included in efficient kits, the actual cost of the measure should be used.

LOADSHAPE

Lighting RES
Lighting BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh_{RES} = (Watt_{Base} - Watt_{EE}) * \%RES * ISR * (1 - LKG) * (Hours_{RES} * WHF_{RES}) / 1{,}000$$

[380] https://www.designlights.org/QPL.
[381] ENERGY STAR®, v2.0: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20AUG-2016.pdf.
[382] Particularly in residential applications, lamps are susceptible to persistence issues such as removal, new fixtures, new occupants etc. The measure life is capped at 19, per TAC agreement 1/19/2017.

ΔkWh_{NRES}=
$(Watt_{Base} - Watt_{EE}) * (1 - \%RES) * ISR * (1 - LKG) * (Hours_{NRES} * Days * WHF_{NRES})/1{,}000$

Where:

$Watts_{Base}$ = Based on bulb type and lumens of LED bulb installed. See table below.

$Watts_{EE}$ = Actual wattage of LED purchased / installed - If unknown, use default provided below:[383]

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$	Delta Watts
Directional	250	349	25	5.6	19.4
	350	399	35	6.3	28.7
	400	599	40	7.5	32.5
	600	749	60	9.7	50.3
	750	999	75	12.7	62.3
	1000	1250	100	16.2	83.8
Decorative	70	89	10	1.8	8.2
	90	149	15	2.7	12.3
	150	299	25	3.2	21.8
	300	499	40	4.7	35.3
	500	699	60	6.9	53.1
Globe	250	349	25	4.1	20.9
	350	499	40	5.9	34.1
	500	574	60	7.6	52.4
	575	649	75	13.6	61.4
	650	1099	100	17.5	82.5
	1100	1300	150	13.0	137.0

%RES = percentage of bulbs sold to residential customers

LKG = leakage rate (program bulbs installed outside Ameren Missouri's service area)

ISR = In Service Rate, the percentage of units rebated that are actually in service

Program	Discounted In Service Rate (ISR)
Retail (Time of Sale)[384]	95.12%
Direct Install[385]	99%
Efficiency Kit (School)	92%
Efficiency Kit (Single Family)[386]	92%
Efficiency Kit (Multi-Family)[387]	98%

$Hours_{RES}$ = Average hours of use per year

[383] $Watts_{EE}$ defaults are based upon the average available ENERGY STAR® product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR® product currently available, $Watts_{EE}$ is based upon the ENERGY STAR® minimum luminous efficacy (directional; 40Lm/W for lamps with rated wattages less than 20Wand 50 Lm/W for lamps with rated wattages ≥ 20 watts. decorative and globe; 45Lm/W for lamps with rated wattages less than 15W, 50lm/W for lamps ≥15 and <25W, 60 Lm/W for lamps with rated wattages ≥ 25 watts.) for the mid-point of the lumen range. See calculation at "cerified-light-bulbs-2015-06-18.xlsx." These assumptions should be reviewed regularly to ensure they represent the available product.

[384] Updated UMP Method (based on initial install value from PY17 inventory).

[385] Ameren Missouri Home Energy Analysis Program Impact and Process Evaluation: Program Year 2015.

[386] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015.

[387] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015.

= Custom, or if unknown assume 728[388] for interior or 1,314 for exterior, or 776 if location is not known.

$Hours_{NRES}$ = 3,613

$WHFe_{Heat}$ = 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[389]

Where:

HF = Heating Factor or percentage of light savings that must now be heated

= 53%[390] 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:[391]

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 and after	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.57[392]

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[393]

$WHFe_{Cool}$ = 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[394]
Building without cooling or exterior	1.0
Unknown	1.11[395]

Summer Coincident Peak Demand Savings

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

Where:

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

Bulb Location	CF
Lighting RES (Residential)	0.0001492529
Lighting BUS (Business)	0.0001899635

Other factors as defined above.

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389 Calculated using defaults: 1-((0.53/1.57) * 0.35) = 0.88.

390 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 were judged to be equally applicable to Missouri.

391 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.

392 Calculation assumes 50% heat pump and 50% resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls." Average efficiency of heat pump is based on assumption 50% are units from before 2006 and 50% 2006-2014.

393 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.

394 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)), 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 were assumed to be applicable to Missouri.

395 The value is estimated at 1.11 (calculated as 1 + (0.91*(0.34 / 2.8)). Based on assumption that 91% of homes have central cooling (based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region.xls").

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated home:s[396]

$$\Delta Therms = -\frac{\frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * HF * 0.03412}{\eta\mathrm{Heat}} * \%\mathrm{GasHeat}$$

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 53%[397] 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%[398]

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[399]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE:

[396] Negative value because this is an increase in heating consumption due to the efficient lighting.

[397] 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.

[398] 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 "HC6.9 Space Heating in Midwest Region.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.

[399] 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

Conventional residential outdoor pool pumps are single speed, often oversized, and run frequently at constant flow regardless of load. Single speed pool pumps require that the motor be sized for the task that requires the highest speed. As such, energy is wasted performing low speed tasks at high speed. Two- speed and variable speed pool pumps reduce speed when less flow is required, such as when filtering is needed but not cleaning, and have timers that encourage programming for fewer on-hours. Variable speed pool pumps use advanced motor technologies to achieve efficiency ratings of 90% while the average single speed pump will have efficiency ratings between 30% and 70%.[400] This measure is the characterization of the purchasing and installing of an efficient two-speed or variable speed residential pool pump motor in place of a standard single speed motor of equivalent horsepower.

This measure was developed to be applicable to the following program types: TOS, NC, 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® two speed or variable speed residential pool pump for in-ground pools.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a single speed residential pool pump.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for a two speed or variable speed pool pump is 10 years.[401]

DEEMED MEASURE COST

The incremental cost is estimated as $235 for a two-speed motor and $549 for a variable speed motor.[402]

LOADSHAPE

Pool Spa RES

Algorithm

CALCULATION OF ENERGY SAVINGS

Electric Energy Savings

$$Energy\ Savings\ \left(\frac{kWh}{Year}\right) = Days_{oper} * \{\left(\frac{kWh_{ss}}{Day}\right) - \left(\frac{kWh_{ds}}{Day}\right)\}$$

$$\left(\frac{kWh_{ds}}{Day}\right) = \left(\frac{kWh_{hs}}{Day}\right) + \left(\frac{kWh_{ls}}{Day}\right)$$

$$\left(\frac{kWh_{ss}}{Day}\right) = (RT_{ss} * GPM_{ss} * 60)/(EF_{ss} * 1000)$$

$$\left(\frac{kWh_{hs}}{Day}\right) = (RT_{hs} * GPM_{hs} * 60)/(EF_{hs} * 1000)$$

$$\left(\frac{kWh_{ls}}{Day}\right) = (RT_{ls} * GPM_{ls} * 60)/(EF_{ls} * 1000)$$

[400] U.S. DOE, 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. Report No. DOE/GO-102012-3534.

[401] The CEE Efficient Residential Swimming Pool Initiative, p18, indicates that the average motor life for pools in use year round is 5-7 years. For pools in use for under a third of a year, you would expect the lifetime to be higher so 10 years is selected as an assumption. This is consistent with DEER, 2014 and the ENERGY STAR® Pool Pump Calculator assumptions.

[402] ENERGY STAR® Pool Pump Calculator.

Where:

Term	Multi speed	Variable Speed
$Days_{oper}$= Days per Year of Operation	*121.6*	*121.6*
RT_{ss} = runtime in hours/day using single speed (ss) pump	11.4	11.4
RT_{ls} = runtime in hours/day in low speed (ls) using dual speed (ds) pump	9.8	10.0
RT_{hs} = runtime in hours/day in high speed (hs) using dual speed (ds) pump	2.0	2.0
GPM_{ss} = gallons per minute using single speed (ss) pump	64.4	64.4
GPM_{ls} = gallons per minute in low speed (ls) using dual speed (ds) pump	31.0	30.6
GPM_{hs} = gallons per minute in high speed (ls) using dual speed (ds) pump	56.0	50.0
EF_{ss} = energy factor (gallons/watt-hr) using single speed (ss) pump	2.1	2.1
EF_{ls} = energy factor (gallons/watt-hr) in low speed (ls) using dual speed (ds) pump	5.4	7.3
EF_{hs} = energy factor (gallons/watt-hr) in high speed (hs) using dual speed (ds) pump	2.4	3.8

Summer Coincident Peak Demand Savings

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0002354459

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.[403] Where this occurs, an algorithm is provided to estimate the site-specific savings. Where test in/test out has not occurred, a conservative deemed 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 15 years.[404]

DEEMED MEASURE COST

The actual capital cost for this measure should be used.

LOADSHAPE

Building Shell RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Test In / Test Out Approach

$$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

$$= \frac{\left(\frac{CFM50_{Pre} - CFM50_{Post}}{N_{cool}}\right) * 60 * 24 * CDD * DUA * 0.018 * LM}{(1000 * \eta Cool)}$$

$CFM50_{Pre}$ = Infiltration at 50 Pascals as measured by blower door before air sealing
= Actual[405]

$CFM50_{Post}$ = Infiltration at 50 Pascals as measured by blower door after air sealing
= Actual

[403] Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.
[404] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.
[405] 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.

N_{cool} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions
=Dependent on number of stories:[406]

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:[407]

Weather Basis (City based upon)	CDD 65
St Louis, MO	1646

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)
= 0.75[408]

0.018 = Specific heat capacity of air (Btu/ft^3*°F)

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of air conditioning equipment (kBtu/kWh)
= Actual (where it is possible to measure or reasonably estimate) - if unknown, assume the following:[409]

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

LM = Latent multiplier to account for latent cooling demand: [410]

Weather Basis (City based upon)	LM
St Louis, MO	3.0

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \frac{\frac{(CFM50_{Pre} - CFM50_{Post})}{N\_heat} * 60 * 24 * HDD * 0.018}{(\eta Heat * 3{,}412)}$$

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions
= Based on building height:[411]

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	4486

ηHeat = Efficiency of heating system

[406] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30-year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets.

[407] Based on climate normals data with a base temperature of 65°F.

[408] This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," p31.

[409] 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.

[410] 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.

[411] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets.

= Actual - if not available refer to default table below:[412]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 and after	8.2	2.04
Resistance	N/A	N/A	1

3412 = Converts Btu to kWh

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[413]

Building Type	HVAC System	SavingsPerUnit (kWh/ft)
Manufactured	Central Air Conditioner	0.062
Multifamily	Central Air Conditioner	0.043
Single Family	Central Air Conditioner	0.050
Manufactured	Electric Furnace/Resistance Space Heat	0.413
Multifamily	Electric Furnace/Resistance Space Heat	0.285
Single Family	Electric Furnace/Resistance Space Heat	0.308
Manufactured	Air Source Heat Pump	0.391
Multifamily	Air Source Heat Pump	0.251
Single Family	Air Source Heat Pump	0.308
Manufactured	Air Source Heat Pump - Cooling	0.062
Multifamily	Air Source Heat Pump - Cooling	0.043
Single Family	Air Source Heat Pump - Cooling	0.050
Manufactured	Air Source Heat Pump - Heating	0.329
Multifamily	Air Source Heat Pump - Heating	0.208
Single Family	Air Source Heat Pump - Heating	0.257

SqFt = Building conditioned square footage
= Actual

Additional Fan savings

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time
= ΔTherms * F_e * 29.3

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[414]

29.3 = kWh per therm

[412] 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.

[413] The values in the table represent estimates of savings from a 15% improvement in air leakage. The values are half those provided by Cadmus for the Iowa Joint Assessment, based on building simulations performed. While 30% savings are certainly achievable, this represents a thorough job in both the attic and basements and could not be verified without testing. The conservative 15% estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

[414] 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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh_cooling = As calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[415]

NATURAL GAS SAVINGS

Test In / Test Out Approach

If natural gas heating:

$$\Delta Therms = \frac{\frac{(CFM50_{Pre} - CFM50_{Post})}{N\_heat} * 60 * 24 * HDD * 0.018}{(\eta Heat * 100{,}000)}$$

Where:

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions
= Based on building height:[416]

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	4486

ηHeat = Efficiency of heating system
= Equipment efficiency * distribution efficiency
= Actual[417] - if not available, use 71%[418]

Other factors as defined above

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[419]

Building Type	HVAC System	SavingsPerUnit (Therms/ft)
Manufactured	Gas Boiler	0.022
Multifamily	Gas Boiler	0.018
Single Family	Gas Boiler	0.016
Manufactured	Gas Furnace	0.017
Multifamily	Gas Furnace	0.012
Single Family	Gas Furnace	0.013

415 Based on Ameren Missouri 2016 loadshape for residential cooling end-use.

416 N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30-year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets.

417 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 - (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf - or by performing duct blaster testing.

418 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.

419 The values in the table represent estimates of savings from a 15% improvement in air leakage. The values are half those provided by Cadmus for the Iowa Joint Assessment, based on building simulations performed. While 30% savings are certainly achievable, this represents a thorough job in both the attic and basements and could not be verified without testing. The conservative 15% estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

SqFt = Building square footage
= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE:

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 25 years.[420]

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

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) * A_{attic} * (1 - FramingFactor_{Attic}) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

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[421])

A_{Attic} = Total area of insulated ceiling/attic (ft^2)

$FramingFactor_{Attic}$ = Adjustment to account for area of framing = 7%[422]

CDD = Cooling Degree Days:[423]

Weather Basis (City based upon)	CDD 65
St Louis, MO	1646

24 = Converts days to hours

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

[421] 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).

[422] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

[423] Based on climate normals data with a base temp of 65°F.

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)
= 0.75[424]
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:[425]

Age of Equipment	ηCool Estimate
Before 2006	10
2006 - 2014	13
Central AC after 1/1/2015	13
Heat Pump after 1/1/2015	14

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) * A_{Attic} * (1 - FramingFactor_{Attic}) * HDD * 24 * ADJAttic}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

Weather Basis (City based upon)	HDD 65
St Louis, MO	4486

ηHeat = Efficiency of heating system
= Actual - if not available, refer to default table below:[426]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.9
	2015 and after	8.2	2.0
Resistance	N/A	N/A	1.0

3412 = Converts Btu to kWh
ADJ_{Attic} = Adjustment for attic insulation to account for prescriptive engineering algorithms consistently overclaiming savings.
= 74%[427]
ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time
= ΔTherms * F_e * 29.3
Where:
F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[428]
29.3 = kWh per therm

[424] This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," p31.
[425] 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.
[426] 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.
[427] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation," August 2012. See "Insulation ADJ calculations.xls" for details or calculation.
[428] 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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[429]

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{attic}}\right) * A_{Attic} * (1 - FramingFactor_{Attic}) * HDD * 24 * ADJAttic}{(\eta Heat * 100{,}000)}$$

Where:

HDD = Heating Degree Days

Weather Basis (City based upon)	HDD 65
St Louis, MO	4486

ηHeat = Efficiency of heating system
= Equipment efficiency * distribution efficiency
= Actual.[430] If unknown, assume 71%.[431]

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:

[429] Based on Ameren Missouri 2016 loadshape for residential cooling end-use.

[430] 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 - (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) - or by performing duct blaster testing.

[431] 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.[432]

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.

$$\Delta kWh = \Delta kWhCooling + \Delta kWhHeating$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWhCooling = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLHcool * \Delta T_{AVG,cooling}}{(1{,}000 * SEER)}$$

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)

EFLHcool = Equivalent Full Load Cooling Hours:[433]

Weather Basis (City based upon)	EFLHcool (Hours)
St Louis, MO	869

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

[433] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren territory suggesting an appropriate EFLH of 869.The other weather basis values are calculated using the relative climate normals cooling degree day ratios (at 65F set point).

$\Delta T_{AVG,cooling}$ = Average temperature difference (^{0}F) during cooling season between outdoor air temperature and assumed 60^{0}F duct supply air temperature[434]

Weather Basis (City based upon)	$OA_{AVG,cooling}$ [°F][435]	$\Delta T_{AVG,cooling}$ [°F]
St Louis, MO	80.8	20.8

1,000 = Converts Btu to kBtu

SEER = Efficiency in SEER of air conditioning equipment

= Actual - If not available, use:[436]

Equipment Type	Age of Equipment	SEER Estimate
Central AC	Before 2006	10
	After 2006	13
Heat Pump	Before 2006	10
	2006-2014	13
	2015 on	14

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:

$$\Delta kWhHeating_{Electric} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLHheat * \Delta T_{AVG,heating}}{(3{,}412 * COP)}$$

Where:

EFLHheat = Equivalent Full Load Heating Hours:[437]

Weather Basis (City based upon)	EFLHheat (Hours)
St Louis, MO	2009

$\Delta T_{AVG,heating}$ = Average temperature difference (^{0}F) during heating season between outdoor air temperature and assumed 115^{0}F duct supply temperature[438]

Weather Basis (City based upon)	$OA_{AVG,heating}$ [°F][439]	$\Delta T_{AVG,heating}$ [°F]
St Louis, MO	43.2	71.8

3,412 = Converts Btu to kWh

COP = Efficiency in COP of heating equipment

= Actual - if not available, use:[440]

System Type	Age of Equipment	HSPF Estimate	COP (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04

[434] Leaving coil air temperatures are typically about 55^{0}F. Therefore, 60^{0}F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

[435] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . 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.

[436] 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.

[437] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other weather basis values are calculated using the climate normals heating degree day ratios (at 60F set point).

[438] Forced air supply temperatures are typically 130^{0}F. 115^{0}F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

[439] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . 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.

[440] 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.

Resistance	N/A	N/A	1

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.

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

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%[441]

29.3 = Converts therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWhCooling * CF$$

Where:

ΔkWhCooling = 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.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLHheat * \Delta T_{AVG,heating}}{(100{,}000 * \eta\text{Heat})}$$

Where:

All factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[441] 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.

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 25 years.[442]

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:

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * Area * (1 - Framing\ Factor) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Old} = R-value value of floor before insulation, assuming 3/4" plywood subfloor and carpet with pad

= Actual -- if unknown, assume 3.96[443]

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

Area = Total floor area to be insulated

Framing Factor = Adjustment to account for area of framing

= 12%[444]

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

[443] Based on 2005 ASHRAE Handbook – Fundamentals: assuming 2x8 joists, 16" OC, ¾" subfloor, ½" carpet with rubber pad, and accounting for a still air film above and below: 1/ [(0.85 cavity share of area / (0.68 + 0.94 + 1.23 + 0.68)) + (0.15 framing share / (0.68 + 7.5" * 1.25 R/in + 0.94 + 1.23 + 0.68))] = 3.96.

[444] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.

24 = Converts hours to days

CDD = Cooling Degree Days

Weather Basis (City based upon)	Unconditioned Space
	CDD 75 [445]
St Louis, MO	762

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75[446]

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:[447]

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

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * Area * (1 - Framing\ Factor) * HDD * 24 * ADJ_{Floor}}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days:

Weather Basis Zone (City based upon)	Unconditioned Space
	HDD 50 [448]
St Louis, MO	1911

ηHeat = Efficiency of heating system

= Actual -- if not available, refer to default table below:[449]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.9
	2015 and after	8.2	2.0
Resistance	N/A	N/A	1.0

ADJ_{Floor} = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings.

= 88%[450]

Other factors as defined above

[445] 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.

[446] Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," p31.

[447] 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.

[448] 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.

[449] 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.

[450] Based upon comparing algorithm-derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation," August 2012. See "Insulation ADJ calculations.xls" for details or calculation. Note that basement wall is used as a proxy for crawlspace ceiling.

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time
= ΔTherms * F_e * 29.3

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[451]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[452]

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * Area * (1 - Framing\ Factor) * HDD * 24 * ADJ_{Floor}}{(\eta Heat * 100{,}000)}$$

Where

ηHeat = Efficiency of heating system
= Equipment efficiency * distribution efficiency
= Actual[453] - If not available, use 71%[454]

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:

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[451] 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.

[452] Based on Ameren Missouri 2016 loadshape for residential cooling end-use.

[453] 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 - (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf - or by performing duct blaster testing.

[454] 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 Foundation Sidewall Insulation

DESCRIPTION

Insulation is added to a basement or crawl space. Insulation added above ground in conditioned space is modeled the same as wall insulation. Below ground insulation is adjusted with an approximation of the thermal resistance of the ground. Insulation in unconditioned spaces is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

This measure was developed to be applicable to the following program 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 basement wall or ceiling insulation.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 25 years.[455]

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 for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to Insulation

$$= \frac{\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

R_{OldAG} = R-value value of foundation wall above grade.
= Actual, if unknown assume 1.0[456]

L_{BWT} = Length (Basement Wall Total) of basement wall around the entire insulated perimeter (ft)

H_{BWAG} = Height (Basement Wall Above Grade) of insulated basement wall above grade (ft)

FF = Framing Factor, an adjustment to account for area of framing when cavity insulation is used
= 0% if spray foam or external rigid foam
= 25% if studs and cavity insulation[457]

24 = Converts hours to days

CDD = Cooling Degree Days
= Dependent whether basement is conditioned:

Weather Basis (City based upon)	Conditioned Space CDD 65 [458]	Unconditioned Space CDD 75 [459]
St Louis, MO	1646	762

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).
= 0.75[460]

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:[461]

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

456 ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991, http://www.ornl.gov/sci/roofs+walls/foundation/ORNL_CON-295.pdf.

457 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

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

459 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.

460 This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," p31.

461 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.

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

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\left(\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})} \right) * L_{BWT} * H_{BWAG} * (1 - FF) \right) + \left(\left(\frac{1}{R_{OldBG}} - \frac{1}{(R_{Added} + R_{OldBG})} \right) * L_{BWT} * (H_{BWT} - H_{BWAG}) * (1 - FF) \right) \right) * HDD * 24 * DUA * ADJ_{Basement}}{(3412 * \eta Heat)}$$

Where

R_{OldBG} = R-value value of foundation wall below grade (including thermal resistance of the earth)[462]

= dependent on depth of foundation (H_basement_wall_total – H_basement_wall_AG):

= Actual R-value of wall plus average earth R-value by depth in table below

For example, for an area that extends 5 feet below grade, an R-value of 7.46 would be selected and added to the existing insulation R-value.

Below Grade R-value									
Depth below grade (ft)	0	1	2	3	4	5	6	7	8
Earth R-value (°F-ft^2-h/Btu)	2.44	4.50	6.30	8.40	10.44	12.66	14.49	17.00	20.00
Average Earth R-value (°F-ft2-h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69
Total BG R-value (earth + R-1.0 foundation) default	3.44	4.47	5.41	6.41	7.42	8.46	9.46	10.53	11.69

H_{BWT} = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on whether basement is conditioned:

Weather Basis (City based upon)	Conditioned Space HDD 65 [463]	Unconditioned Space HDD 50 [464]
St Louis, MO	4486	1,911

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[465]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.9
	2015 and after	8.2	2.0
Resistance	N/A	N/A	1.0

[462] Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook.

[463] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004.

[464] 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.

[465] 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.

$ADJ_{Basement}$ = Adjustment for basement wall insulation to account for prescriptiveengineering algorithms overclaiming savings.
= 88%[466]

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time
= ΔTherms * F_e * 29.3

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[467]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[468]

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms =

$$= \frac{\left(\left(\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF)\right) + \left(\left(\frac{1}{R_{OldBG}} - \frac{1}{(R_{Added} + R_{OldBG})}\right) * L_{BWT} * (H_{BWT} - H_{BWAG}) * (1 - FF)\right)\right) * HDD * 24 * ADJ_{Basement}}{(100{,}000 * \eta Heat)}$$

Where

ηHeat = Efficiency of heating system
= Equipment efficiency * distribution efficiency
= Actual[469] - If not available, use 71%[470]

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:

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[466] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation," August 2012. See "Insulation ADJ calculations.xls" for details or calculation.

[467] 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.

[468] Based on Ameren Missouri 2016 loadshape for residential cooling end-use.

[469] 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 - (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf - or by performing duct blaster testing.

[470] 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.

3.7.6 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[471]

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.[472] For clear glazing, cost can be assumed as $6.72/ft^2 of window area (material cost) plus $30 per window for installation expenses.[473]

LOADSHAPE
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[471] 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, September 2013. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory. PNNL-22864.
[472] 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, September 2013. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory. PNNL-22864.
[473] 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.

Algorithm

CALCULATION OF SAVINGS

The following reference tables show savings factors (kBtu/ft^2) for both heating and cooling loads for each of the seven weather zones defined by the TRM.[474] 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.

St Louis, MO

Heating:

Savings in kBtu/ft^2		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 in kBtu/ft^2		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:

ΔkWh_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

$$= \frac{\Sigma_{cool} * A}{\eta Cool}$$

Σ_{cool} = Savings factor for cooling, as tabulated above.

A = Area (square footage) of storm windows installed.

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

= Actual (where it is possible to measure or reasonably estimate) - If unknown, assume the following:[475]

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

[474] Savings factors are based on simulation results, documented in "Storm Windows Savings.xlsx."

[475] 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.

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \frac{\Sigma_{heat} * A}{\eta Heat * 3.412}$$

Σ_{heat} = Savings factor for heating, as tabulated above.

ηHeat = Efficiency of heating system

= Actual - If not available refer to default table below:[476]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 and after	8.2	2.04
Resistance	N/A	N/A	1

3.412 = Converts kBtu to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh_cooling = As calculated above.

CF = Summer System Peak Coincidence Factor for Cooling

= 0.0009474181[477]

NATURAL GAS SAVINGS

If Natural Gas heating:

$$\Delta Therms = \frac{\Sigma_{heat} * A}{\eta Heat * 100}$$

Where:

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[478] - If not available, use 71%[479]

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

MEASURE CODE:

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[476] 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.

[477] Based on Ameren Missouri 2016 loadshape for residential cooling end-use.

[478] 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 - (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf - or by performing duct blaster testing.

[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). 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.

3.7.7 Kneewall and Sillbox Insulation

DESCRIPTION
This measure describes savings from adding insulation (for example, blown cellulose, spray foam) to wall cavities (this includes kneewall and sillbox areas). 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 and is likely to be empty wall cavities.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 25 years.[480]

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

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Wall}}\right) * A_{Wall} * (1 - FramingFactor_{Wall}) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Wall} = R-value of new wall 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 (ft^2.°F.h/Btu)
(Minimum of R-5 for uninsulated assemblies[481])

A_{Wall} = Net area of insulated wall (ft^2)

$FramingFactor_{Wall}$ = Adjustment to account for area of framing
= 25%[482]

CDD = Cooling Degree Days:[483]

Weather Basis (City based upon)	CDD 65
St Louis, MO	1646

24 = Converts days to hours

[480] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.
[481] 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).
[482] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.
[483] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temperature of 65°F.

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)
= 0.75[484]

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:[485]

Age of Equipment	ηCool Estimate
Before 2006	10
2006 - 2014	13
Central AC after 1/1/2015	13
Heat Pump after 1/1/2015	14

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Wall}}\right) * A_{wall} * (1 - FramingFactor_{Wall}) * HDD * 24 * ADJWall}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days:[486]

Weather Basis (City based upon)	HDD 65
St Louis, MO	4486

ηHeat = Efficiency of heating system
= Actual - If not available, refer to default table below:[487]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.9
	2015 and after	8.2	2.0
Resistance	N/A	N/A	1.0

3412 = Converts Btu to kWh

ADJ_{Wall} = Adjustment for wall insulation to account for prescriptive engineering algorithms consistently overclaiming savings
= 63%[488]

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time
= ΔTherms * F_e * 29.3
Where:
F_e = Furnace fan energy consumption as a percentage of annual fuel consumption
= 3.14%[489]
29.3 = kWh per therm

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484 This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," p31.

485 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.

486 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004.

487 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.

488 Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation," August 2012. See "Insulation ADJ calculations.xls" for details or calculation.

489 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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor
= 0.0009474181[490]

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{wall}}\right) * A_{wall} * (1 - FramingFactor_{Wall}) * HDD * 24 * ADJWall}{(\eta Heat * 100{,}000)}$$

Where:

HDD = Heating Degree Days:[491]

Weather Basis (City based upon)	HDD 65
St Louis, MO	4486

ηHeat = Efficiency of heating system
= Equipment efficiency * distribution efficiency
= Actual[492] - If not available, use 71%[493]

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:

[490] Based on Ameren Missouri 2016 loadshape for residential cooling end-use.

[491] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004.

[492] 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 - (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf - or by performing duct blaster testing.

[493] 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.

3.8 Miscellaneous

3.8.1 Home Energy Report

DESCRIPTION

These behavior/feedback programs send energy use reports to participating residential electric or gas customers in order to change customers' energy use behavior. Savings impacts are evaluated by ex-post billing analysis comparing consumption before and after (or with and without) program intervention and require M&V methods that include customer-specific energy usage regression analysis and randomized controlled trial (RCT) experimental designs, among others (see national protocols developed under the sponsorship of the US Department of Energy[494]). As such, calculation of savings achieved by the program for the year is treated as a custom protocol.

Given that actual monitored energy use is needed, as an ex-post input for these custom calculations, estimates of program savings are used for program planning and goal setting at the beginning of the program cycles. Estimated deemed values are based on previous actual program performance developed through forecasting analysis from the program implementer, or taken from actual savings values from comparable programs delivered by other program administrators.

HER Program Deemed Savings Estimates for 2016-2018 Planning

Utility Program	Gross Electric Savings (kWh/home)	Gross Demand Savings (kW/home)
Ameren Missouri Home Energy Report[495]	150	.07

DEFINITION OF EFFICIENT CASE

The efficient case is a customer who receives an HER.

DEFINITION OF BASELINE CASE

The baseline case is a customer who does not receive an HER.

DEEMED LIFETIME OF PROGRAM SAVINGS

The expected measure life is assumed to be 1 year.

DEEMED MEASURE COST

It is assumed that most behavior changes in residential settings can be accomplished with homeowner labor only and without investment in new equipment. Therefore, without evidence to the contrary, measure costs in such residential programs focused on motivating changes in customer behavior may be defined as $0.

LOADSHAPE

Building Shell RES

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[494] Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations; SEEAction (State and Local Energy Efficiency Action Network- EPA/DOE), 2012; The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures; Residential Behavior Protocol, NREL/ DOE, 2015.

[495] The deemed values used by Ameren Missouri for planning purposed are derived by finding a reasonable medium between the average of 147 kWh savings/participant/year (per the KCP&L GMO 2016-2018 plan filed on August 28, 2015; KCPL MEEIA Report with Appendices NP 8-28-2015.pdf) and the average of 154 kWh savings/participation/year (per the KCP&L GMO 2016-2018 plan filed August 28, 2015; GMO MEEIA Report with Appendices NP 8-28-2015.pdf).

3.8.2 Demand Response Advanced Thermostat

DESCRIPTION

This measure characterizes the energy and demand savings for an advanced thermostat enrolled in the Residential DR Program. The program controls customer energy loads and also reduces energy usage by utilizing a continuous load shaping strategy during non-peak hours. Savings impacts are evaluated by ex-post analysis comparing demand and consumption with and without program intervention, utilizing field data which may be available through advanced thermostats' 2-way communication ability. The program will require M&V methods that include customer-specific energy usage regression analysis and randomized controlled trial (RCT) experimental designs, among others. As such, calculation of both demand and energy savings achieved by the program for the year are treated as a custom protocol.

Given that actual monitored field data is needed as ex-post inputs for these custom calculations, estimates of program savings are used for program planning and goal setting at the beginning of the program cycles.

Demand Response Smart Thermostat Deemed Savings Estimates for 2019-2024 Planning[496]

Utility Program	Gross Electric Savings (*Annual*) (kWh/thermostat)	Gross Demand Savings (*Event*) (kW/thermostat)[497]
Demand Response Advanced Thermostat	177	1.53

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

DEFINITION OF EFFICIENT CASE

The efficient case is a customer who participated in the DR program.

DEFINITION OF BASELINE CASE

The baseline case is a customer who is not participating in the DR program and who has installed a thermostat with default enabled capability—or the capability to automatically—establish a schedule of temperature set points according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. This category of products and services is broad and rapidly advancing with regard to their capability, usability, and sophistication, but at a minimum the baseline customer must have installed a thermostat capable of two-way communication and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

DEEMED LIFETIME OF PROGRAM SAVINGS

The expected measure life is assumed to be 11 years.

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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[496] Estimated deemed values are developed through forecasting analysis from the program implementer using actual program performance taken from comparable programs delivered by other program administrators. Gross annual energy savings are those associated with a continuous load shaping strategy applied throughout the year during non-peak hours. Gross event demand savings are those associated with demand response events.

[497] Actual average event demand reductions weather normalized to historical system peak conditions. Temperatures coincident with system peak events averaged 99°F from 1981-2010. Residential DR event kW savings will be normalized to this temperature.