Volume 3: Residential Measures

Final

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Volume 3: Residential Measures

3.1 Appliances End Use

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 that used 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 types: ERET.

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

DEFINITION OF EFFICIENT EQUIPMENT

N/A

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated remaining useful life of the recycling units is 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[3] per unit.

LOADSHAPE

Residential Refrigerator

Residential Freezer

[1] Cadmus, 2011; "2010 Residential Great Refrigerator Roundup Program – Impact Evaluation"

[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.

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

Regression analysis; Refrigerators

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

= Dependent on location[5]:

Climate Zone (City based upon)	CDD 65
North East (Fort Madison, IA)	1200
North West (Lincoln, NE)	1174

[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.

Climate Zone (City based upon)	CDD 65
South East (Cape Girardeau, MO)	1453
South West (Kaiser, MO)	1344
St Louis, MO	1646
Kansas City, MO	1360
Average/Unknown (Knob Noster)	1278

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

HDD = Heating Degree Days

= Dependent on location:[6]

Climate Zone (City based upon)	HDD 60
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	3528
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037

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]

Deemed approach; Refrigerators

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

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

[6] Based on Climate Normals HDD data, with a base temp of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[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.

= 1028 kWh

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

[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.

available, part-use factor participant survey results should be used. If not available, assume 0.84.[13]

ΔkWh_{Unit} = 1061 * 0.85

= 891 kWh

Additional Waste Heat Impacts

Only for retired units from conditioned spaces in the home (if unknown, assume unit is from unconditioned space).

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

Where:

ΔkWh_{unit} = 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

= 43% for unit in heated space[14]

= 0% for unit in unheated space or unknown

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

= Actual - If not available, use[15]:

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	1.17[16]

%ElecHeat = Percentage of home with electric heat

[13] Most recent refrigerator part-use factor from Ameren Missouri PY15 evaluation.

[14] Based on 157 days where HDD 60>0, divided by 365.25. HDD days determined from Climate Normals data with a base temp of 60°F NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[15] 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.

[16] 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.

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	35%[17]

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

= (CoolF / ηCool) * %Cool

If unknown, assume 0

CoolF = Cooling Factor or percentage of reduced waste heat that no longer needs to be cooled

= 53% for unit in cooled space[18]

= 0% for unit in uncooled space or unknown

ηCool = Efficiency in COP of Cooling equipment

= Actual - If not available, assume 2.8 COP[19]

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91%[20]

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[21]

Refrigerators = 0.0001285253

Freezers = 0.0001685722

NATURAL GAS SAVINGS

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

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

[17] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls".
[18] Based on 193 days where CDD 65>0, divided by 365.25. CDD days determined from Climate Normals data with a base temp of 65°F.
[19] 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).
[20] Based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region.xls"
[21] Based on Ameren Missouri 2016 Loadshape for Residential Refrigeration and Freezer End-Use

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

= 43% for unit in heated space[22]

= 0% for unit in heated space or unknown

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

=71%[23]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[24]

0.03412 = Converts kWh to Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RFRC-V01-170331

[22] Based on 157 days where HDD 60>0, divided by 365.25. HDD days determined from Climate Normals data with a base temp of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[23] 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 and 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.

[24] 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, NC.

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

DEFINITION OF EFFICIENT EQUIPMENT

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

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust[25] to be considered under this specification.
- Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)
- Standby Power Requirement: = 2.0 Watts Qualifying models that perform secondary consumer functions (e.g. clock, remote control) must meet the standby power requirement.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a conventional unit[26].

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 9 years[27].

DEEMED MEASURE COST

The incremental cost for this measure is $0[28].

LOADSHAPE

Flat

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS[29]

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

Where:

[25] Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard
[26] As defined as the average of non-ENERGY STAR products found in EPA research, 2011, ENERGY STAR Qualified Room Air Cleaner Calculator.
[27] ENERGY STAR Qualified Room Air Cleaner Calculator.
[28] ENERGY STAR Qualified Room Air Cleaner Calculator.
[29] ENERGY STAR Qualified Room Air Cleaner Calculator.

kWh_{BASE} = Baseline kWh consumption per year

= see table below

kWh_{ESTAR} = ENERGY STAR kWh consumption per year

= see table below

Clean Air Delivery Rate (CADR)	CADR used in calculation (midpoint)	Baseline Unit Energy Consumption (kWh/year)	ENERGY STAR Unit Energy Consumption (kWh/year)	ΔkWH
CADR 51-100	75	441	148	293
CADR 101-150	125	733	245	488
CADR 151-200	175	1025	342	683
CADR 201-250	225	1317	440	877
CADR Over 250	300	1755	586	1169

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 8760 hours[30]

Clean Air Delivery Rate	ΔkW
CADR 51-100	0.033
CADR 101-150	0.056
CADR 151-200	0.078
CADR 201-250	0.100
CADR Over 250	0.133

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

There are no operation and maintenance cost adjustments for this measure.[31]

MEASURE CODE: RS-APL-ESAP-V01-170331

[30] Assumes constant use throughout the entire year; 8766 hours.

[31] 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[32]. ENERGY STAR provides criteria for both gas and electric clothes dryers.

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years[33].

DEEMED MEASURE COST

Dryer Size	Incremental Cost[34]
Standard	$75
Compact	$105

LOADSHAPE

Loadshape - Residential Clothes Dryer

[32] 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

[33] 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

[34] 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)[35]
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[36]. 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[37]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.[38] 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[39]

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year. [40]

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

[36] ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis

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

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

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

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

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 5% for gas dryers[41]

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

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

= 0.0001720545[42]

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

41 %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 5% 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 EnergySTAR appliance calculator.

42 Itron eShapes, 8760 hourly data by end use for Missouri. The overall average of annual unitized demand values was determined for Month 7, Day 21, Hour 17, representing system peak loading.

= 0% for electric units and 84% for gas units[43]

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: RS-APL-ESDR-V01-170331

[43] %Gas accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 84% was determined using a ratio of the gas to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

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. Note 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, 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[44].

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" [45].

[44] See http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

[45] Definitions provided in ENERGY STAR v7.1 specification on the Energy star website.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years[46].

DEEMED MEASURE COST

The incremental cost assumptions are provided below[47]:

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

LOADSHAPE

Loadshape Residential Clothes Washer

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Capacity = Clothes Washer capacity (cubic feet)

= Actual - If capacity is unknown, assume 3.45 cubic feet [48]

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[49]
Federal Standard	1.29	1.84	1.66

[46] Based on DOE Chapter 8 Life-Cycle Cost and Payback Period Analysis.

[47] 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.

[48] 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.

[49] 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":

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[50]
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[51]

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

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

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

	Percentage of Total Energy Consumption[52]		
	%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%

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%

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

[51] 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 MO): 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 multi-family homes, in a particular market, or geographical area then that should be used.

[52] 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.

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

DHW fuel	$\%Electric_{DHW}$
Electric	100%
Natural Gas	0%
Unknown	43%[53]

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

Dryer fuel	$\%Electric_{Dryer}$
Electric	100%
Natural Gas	0%
Unknown	90%[54]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below[55]:

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

Weighted Average:

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

[54] 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 MO. 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.

[55] 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.

	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

= 0.0001506681[56]

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	0.033	0.020	0.018	0.004

56 Itron eShapes, 8766 hourly data by end use for Missouri. The overall average of annual unitized demand values was determined for Month 7, Day 21, Hour 17, representing system peak loading.

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
Tier 2				
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%[57]

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

R_eff = Recovery efficiency factor

= 1.26[58]

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

Dryer fuel	$\%Gas_{Dryer}$
Electric	0%
Natural Gas	100%
Unknown	10%[59]

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

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	0.0	6.1	2.9	9.0

[58] 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.

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

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
Tier 2				
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[60]

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[61]			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

60 Weighted average IWF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR product in the CEC database.

61 IWF values are the weighted average of the new ENERGY STAR specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and ENERGY STAR Most Efficient product in the CEC database. See “2015 Clothes Washer Analysis.xls” for the calculation.

MEASURE CODE: RS-APL-CLWA-V01-170331

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, 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 shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

DEFINITION OF BASELINE EQUIPMENT

The baseline for this measure is defined as a new dehumidifier that meets the Federal 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[62].

DEEMED MEASURE COST

The assumed incremental capital cost for this measure is $5[63].

LOADSHAPE

Residential Dehumidifier

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62 Lifetime determined by EPA research, 2012. ENERGY STAR Qualified Room Air Cleaner Calculator. (ENERGY STAR Appliance Calculator.xlsx)

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (((Avg\ Capacity * 0.473) / 24) * Hours) * (1 / (L/kWh\_Base) – 1 / (L/kWh\_Eff))$$

Where:

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

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

0.473 = Constant to convert Pints to Liters

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

Hours = Run hours per year

= 1632 [64]

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[65]						204

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

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

= 0.0006127451[66]

64 Based on 24 hour operation over 68 days of the year. ENERGY STAR Qualified Room Air Cleaner Calculator. (ENERGY STAR Appliance Calculator.xlsx)

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

66 Assume usage is evenly distributed day vs. night, weekend vs. weekday and overlaps with the summer peak period definition. Total operating hours is assumed to be 1632 from ENERGY STAR Dehumidifier Calculator, giving a factor of 1/1632 or 0.0006127451.

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: RS-APL-ESDH-V01-170331

3.1.6 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 time of sale 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, 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 meeting 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

17 years[67]

DEEMED MEASURE COST

The full cost of a baseline unit is $742.[68]

The incremental cost to the Energy Star level is $11, to CEE Tier 2 level is $20 and to CEE Tier 3 is $59.[69]

LOADSHAPE

Residential Refrigeration

[67] 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

[68] 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

[69] 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,[70] assuming 22.5 ft^3 adjusted volume[71]

= Calculated using algorithms in table below, or using defaults provided based on 22.5 ft^3 adjusted volume[72]

%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%

<u>Additional Waste Heat Impacts</u>

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

= 69% for unit in heated space or unknown [73]

= 0% for unit in unheated space

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

[70] According to Federal Standard effective 9/15/14

[71] DOE Building Energy Data Book, http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.5

[72] DOE Building Energy Data Book, http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.5

[73] Based on 252 days where HDD 60>0, divided by 365.25. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

= Actual - If not available, use table below[74]:

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[75]

%ElecHeat = Percentage of home with electric heat

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	35%[76]

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

= 53% for unit in cooled space or unknown [77]

= 0% for unit in uncooled space

ηCool = Efficiency in COP of Cooling equipment

= Actual - If not available, assume 2.8 COP[78]

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91%[79]

Algorithms for the most common refrigerator configurations, kWh_{base}, $\Delta kWh_{WasteHeat}$ for unknown

[74] 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.

[75] 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.

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

[77] Based on 193 days where CDD 65>0, divided by 365.25.

[78] 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).

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

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

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[80]	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)	52%	59.2	88.8	118.4	-1.0	-1.5	-1.9	58.2	87.3	116.5
Side-by-Side w/ TTD (PC 7)	22%									
Bottom Freezer (PC 5)	13%									
Bottom Freezer w/ TTD (PC 5A)	13%									

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

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

= 0.0001285253[81]

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:

Product Class	Market Weight[82]	ΔkW		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	52%	0.0089	0.0134	0.0178
Side-by-Side w/ TTD (PC 7)	22%			
Bottom Freezer (PC 5)	13%			
Bottom Freezer w/ TTD (PC 5A)	13%			

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

= 69% for unit in heated space or unknown [83]

= 0% for unit in unheated space

[81] Based on Ameren Missouri 2016 Loadshape for Residential Refrigeration End-Use

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

[83] Based on 252 days where HDD 60>0, divided by 365.25. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

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

=74%[84]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[85]

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[86]	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

[84] 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.

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

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

MEASURE CODE: RS-APL-REFR-V01-170331

3.1.7 Room Air Conditioner Recycling

DESCRIPTION

This measure describes the savings resulting from running a drop-off service taking existing residential, inefficient Room Air Conditioner units from service prior to their natural end of life. This measure assumes that 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 types: ERET.

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed remaining useful life of the existing room air conditioning unit being retired is 4 years[87].

DEEMED MEASURE COST

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

LOADSHAPE

Residential Cooling

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

[87] One third of assumed measure life for Room AC.

Climate Zone (City based upon)	Hours[88]
North East (Fort Madison, IA)	406
North West (Lincoln, NE)	397
South East (Cape Girardeau, MO)	491
South West (Kaiser, MO)	454
St Louis, MO	556
Kansas City, MO	460
Average/Unknown (Knob Noster)	432

BtuH = Average size of rebated unit. Use actual if available - if not, assume 8500[89]

EERexist = Efficiency of recycled unit

= Actual if recorded - If not, assume 9.0[90]

%replaced = Percentage of units dropped off that are replaced

Scenario	%replaced
Customer states unit will not be replaced	0%
Customer states unit will be replaced	100%
Unknown	76%[91]

EERbase = Efficiency of baseline unit

= 10.9[92]

Results using defaults provided above:

[88] The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008: 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.

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

[90] 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 RAC. 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

[91] 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.

[92] 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

Climate Zone (City based upon)	ΔkWh		
	Unit not replaced	Unit replaced	Unknown
North East (Fort Madison, IA)	383.0	66.8	142.7
North West (Lincoln, NE)	374.7	65.3	139.6
South East (Cape Girardeau, MO)	463.8	80.8	172.7
South West (Kaiser, MO)	429.0	74.8	159.8
St Louis, MO	525.4	91.6	195.7
Kansas City, MO	434.1	75.7	161.7
Average/Unknown (Knob Noster)	407.9	71.1	151.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.0009474181[93]

Results using defaults provided above:

Climate Zone (City based upon)	DkW		
	Unit not replaced	Unit replaced	Unknown
North East (Fort Madison, IA)	0.3629	0.0633	0.1352
North West (Lincoln, NE)	0.3550	0.0619	0.1322
South East (Cape Girardeau, MO)	0.4394	0.0766	0.1637
South West (Kaiser, MO)	0.4064	0.0708	0.1514
St Louis, MO	0.4978	0.0868	0.1854
Kansas City, MO	0.4113	0.0717	0.1532
Average/Unknown (Knob Noster)	0.3865	0.0674	0.1440

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RARC-V01-170331

93 Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use

3.1.8 Refrigerator Coil Cleaning

This measure was not characterized for Version 1 of the Missouri Statewide TRM

3.1.9 Water Cooler

This measure was not characterized for Version 1 of the Missouri Statewide TRM

3.2 Electronics End Use

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 so 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, 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[94].

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[95].

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

LOADSHAPE

Residential Miscellaneous

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

95 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[96]

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

Installation Location	$Weighting_{Office}$
Home Office	100%
Home Entertainment System	0%
Unknown[97]	TOS, NC, DI: 36% KITS: 48%

kWh_{Ent} = Estimated energy savings from using an APS in a home entertainment system

= 75.1 kWh[98]

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

Installation Location	$Weighting_{Ent}$
Home Office	0%
Home Entertainment System	100%
Unknown[99]	TOS, NC, DI: 64% KITS: 52%

ISR = In service rate, dependent on program type

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

[96] "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.

[97] 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.

[98] "Advanced Power Strip Research Report."

[99] 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.

[100] "Ameren Missouri Efficient Product Impact and Process Evaluation: Program Year 2015."

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

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

= 0.0001148238[101]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-CEL-APS1-V01-170331

[101] 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.”

3.2.2 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[102], 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 types: 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[103].

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[104].

DEEMED MEASURE COST

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

LOADSHAPE

Residential Miscellaneous

[102] Tier 2 AV APS identify when people are not engaged with their AV equipment and then remove power - for example, a TV and its peripheral devices that are unintentionally left on when a person leaves the house or falls asleep while watching television.
[103] 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.
[104] "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:[105]

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[106]

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[107]

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105 Based on field test data for various APS products.

106 "Energy Savings of Tier 2 Advanced Power Strips in Residential AV Systems," AESC, Inc., February 2016. Note that this load represents the average *controlled* AV devices only and will likely be lower than total AV usage.

107 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."

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-CEL-APS2-V01-170331

3.3 Hot Water End Use

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, 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.[108]

DEEMED MEASURE COST

The incremental cost for this measure is $11.33[109] or program actual.

For faucet aerators provided in Efficiency Kits, the actual program delivery costs should be utilized.

LOADSHAPE

Residential Electric DHW

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[110] (unless faucet type is unknown, then it is per household).

[108] 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"

[109] Direct-install price per showerhead assumes cost of showerhead (Market research average of $3 and 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).

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

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%[111]

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.

= 1.39[112] or custom based on metering studies[113] or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[114]

GPM_low = Average flow rate, in gallons per minute, of the low-flow faucet aerator "as-used"

= 0.94[115] or custom based on metering studies[116] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[117]

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:

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

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

[113] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[114] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

[115] 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.

[116] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[117] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

Faucet Type	L_base (min/person/day)
Kitchen	4.5[118]
Bathroom	1.6[119]
If location unknown (total for household): Single-Family	7.8[120]
If location unknown (total for household): Multi-Family	6.7[121]

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[122]
Bathroom	1.6[123]
If location unknown (total for household): Single-Family	7.8[124]
If location unknown (total for household): Multi-Family	6.7[125]

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.67[126]
Multi-Family - Deemed	2.07[127]
Custom	Actual Occupancy or Number of Bedrooms[128]

118 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 multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.
119 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 multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.
120 One kitchen faucet plus 2.04 bathroom faucets. Based on findings from a 2012 Ameren Missouri potential study for single family homes.
121 One kitchen faucet plus 1.4 bathroom faucets. Based on findings from an Ameren Missouri PY13 data for multifamily homes.
122 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
123 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
124 One kitchen faucet plus 2.04 bathroom faucets. Based on findings from a 2012 Ameren Missouri potential study for single family homes.
125 One kitchen faucet plus 1.4 bathroom faucets. Based on findings from an Ameren Missouri PY13 data for multifamily homes.
126 Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.
127 Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.
128 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[129]
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[130]
Bathroom Faucets Per Home (BFPH): Multi-Family	1.4[131]
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[132]

SupplyTemp = Assumed temperature of water entering house

= 60.83F [133]

[129] 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.

[130] Based on findings from a 2012 Ameren Missouri potential study for single family homes.

[131] Based on findings from an Ameren Missouri PY13 data for multifamily homes

[132] 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.

[133] Based on the DOE's Building America Standard DHW Event Schedule calculator. Average annual water main temperatures

RE_electric = Recovery efficiency of electric water heater

= 98% [134]

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[135]
Efficiency Kit—Single Family	0.52[136]
Efficiency Kit—Multi Family	1.0[137]

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[138]

NATURAL GAS SAVINGS

ΔTherms = %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%[139]

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[140]

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.

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

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

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

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

[138] Based on Ameren Missouri 2016 Loadshape for Residential Water Heating End-Use.

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

[140] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for

= 67% For MF homes[141]

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

Δgallons = ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * ISR

Variables as defined above.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-LFFA-V01-170331

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%.

[141] Water heating in multi-family 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 multi-family buildings.

3.3.2 Low Flow Showerhead

DESCRIPTION

This measure relates to the installation of a low flow showerhead in a single or multi-family household.

This measure may be used for units provided through Efficiency 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, 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 Direct-install programs, the baseline condition is assumed to be a standard showerhead rated at 2.5 GPM[142] or greater.

For retrofit and time-of-sale programs, the baseline condition is assumed to be a representative average of existing showerhead flow rates of participating customers including a range of low flow showerheads, standard-flow showerheads, and high-flow showerheads.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[143]

DEEMED MEASURE COST

The incremental cost for time of sale, new construction or efficiency kits is $7[144] or program actual.

For low flow showerheads provided in retrofit or direct install programs, the actual program delivery costs should be utilized, if unknown assume $15.33[145].

LOADSHAPE

Residential Electric DHW

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture

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142 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"

143 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 Multi-Family , "http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf"

144 Based on online pricing market research 2/6/2017.

145 Direct-install price per showerhead assumes cost of showerhead (Market research average of $7 and 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).

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%[146]

GPM_base = Flow rate of the baseline showerhead

Program	GPM_base
Direct-install	2.35[147]
Retrofit, Efficiency Kits, NC or TOS	2.35[148]

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

Rated Flow
2.0 GPM
1.75 GPM
1.5 GPM
Custom or Actual[149]

L_base = Shower length in minutes with baseline showerhead

= 7.8 min[150]

L_low = Shower length in minutes with low-flow showerhead

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

[147] Based on Ameren MO 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.

[148] 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.

[149] 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.

[150] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

= 7.8 min[151]

Household = Average number of people per household

Household Unit Type[152]	Household
Single-Family - Deemed	2.67[153]
Multi-Family - Deemed	2.07[154]
Custom	Actual Occupancy or Number of Bedrooms[155]

SPCD = Showers Per Capita Per Day

= 0.6[156]

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[157]
Multi-Family	1.4[158]
Custom	Actual

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 60.83)) / (0.98 * 3412)

= 0.100 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

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

ShowerTemp = Assumed temperature of water

= 101.0 F [159]

151 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 multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

152 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

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

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

155 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.

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

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

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

159 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to

SupplyTemp = Assumed temperature of water entering house

= 60.83 F [160]

RE_electric = Recovery efficiency of electric water heater

= 98% [161]

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[162]
Efficiency Kit—Single Family	0.47[163]
Efficiency Kit—Multi Family	0.86[164]

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[165]

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%[166]

Michigan Evaluation Working Group.

[160] 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.

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

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

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

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

[165] Based on Ameren Missouri 2016 Loadshape for Residential Water Heating End-Use.

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

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00429 Therm/gal for SF homes

= 0.00499 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[167]

= 67% For MF homes[168]

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: RS-HWE-LFSH-V01-170331

[167] 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%.

[168] Water heating in multi-family 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 multi-family buildings.

3.3.3 Water Heater

Description

This measure applies to gas water heaters under the following program types:

a) Time of Sale or New Construction:
The purchase and installation of a new, residential gas-fired storage or tankless water heater meeting program energy factor (EF) requirements, in place of a unit meeting federal standards.

b) Early Replacement:
The early removal of an existing and functioning, residential gas-fired storage or tankless water heater, prior to its natural end of life, and replacement with a new unit meeting program EF requirements. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a residential gas-fired storage water heater with a maximum heat input rating of 75,000 Btu/hr or a tankless water heater meeting the EF requirements within the table below.[169]

Water Heater Type	EF
Gas Storage ≥20 gal and ≤55 gal	0.67
Gas Storage >55 gal and ≤100 gal	0.77
Gas Tankless	0.90

Definition of Baseline Equipment

Time of Sale or New Construction: The baseline equipment is assumed to be a new, gas-fired storage or tankless residential water heater meeting the minimum federal efficiency standards.[170] For 20 to 55 gallon tanks, the federal standard is calculated as 0.675 – (0.0015 * rated storage size in gallons), for 55 - 100 gallon tanks, the calculation is 0.8012 – (0.00078 * rated storage size in gallons), and for tankless units, the calculation is 0.82 – (0.0019 * rated storage size in gallons).

Early Replacement: The baseline is the efficiency of the existing gas water heater for the remaining useful life of the unit and the efficiency of a new gas water heater meeting minimum federal efficiency standards for the remainder of the measure life.

Deemed Lifetime of Efficient Equipment

Time of Sale or New Construction: The expected measure life is assumed to be 13 years for a gas storage water heater and 20 years for a gas tankless water heater.[171]

For Early Replacement: The remaining life of existing equipment is assumed to be 3.67 for gas storage

[169] ENERGY STAR Product Specification for Residential Water Heaters, Version 3.0, effective April 16, 2015
[170] 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
[171] 2010 Residential Heating Products Final Rule Technical Support Document, U.S. DOE, Table 8.7.1.

water heaters and 6.67 years for gas tankless water heaters.[172]

DEEMED MEASURE COST

Time of Sale or New Construction: The incremental capital cost for this measure is dependent on the type of water heater, as listed below.[173]

Early Replacement: The full installed cost is provided in the table below. The assumed deferred cost (after 4 years) of replacing existing equipment with a new baseline unit is assumed to be $799 for storage units 20 gal and ≤55 gal, and $593 for tankless units.[174] This cost should be discounted to present value using the utility's discount rate.

Actual costs should be used where available.

Water Heater Type	Incremental Cost	Full Install Cost[175]
Gas Storage ≥20 gal and ≤55 gal	$256	$1,055
Gas Tankless	$510	$1,103

LOADSHAPE

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = (1/EF_{Base} - 1/EF_{EE}) * (GPD * Household * 365.25 * \gamma Water * (T_{Out} - T_{In}) * 1.0)/100{,}000$$

Early Replacement:[176]

ΔTherms for remaining life of existing unit (1st 3.67 years for gas storage unit and 1st 6.67 years

172 Database for Energy-Efficiency Resources (DEER), "DEER2014 EUL Table Update," California Public Utilities Commission, February 4, 2014.

173 Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I_August2016.xls" for more information.

174 Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I.xls" for more information.

175 Full install costs reflect 4.54 hours of labor at a labor rate of $78.19 per hour.

176 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 require a first year savings calculation (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).

for gas tankless unit):

$$\Delta Therms = (1/EF_{Existing} - 1/EF_{EE}) * (GPD * Household * 365.25 * \gamma Water * (T_{Out} - T_{In}) * 1.0)/100{,}000$$

ΔTherms for remaining measure life (next 7.33 years for gas storage unit and next 13.33 years for gas tankless unit):

$$\Delta Therms = (1/EF_{Base} - 1/EF_{EE}) * (GPD * Household * 365.25 * \gamma Water * (T_{Out} - T_{In}) * 1.0)/100{,}000$$

Where:

EF_{Base} = EF of standard gas water heater according to federal standards

= For gas storage water heaters with storage capacity ≥20 gallons and ≤55 gallons: 0.675 – (0.0015 * storage capacity in gallons)

= For gas storage water heaters with storage capacity >55 gallons and ≤100 gallons: 0.8012 – (0.00078 * storage capacity in gallons)

= For gas tankless water heaters: 0.82 – (0.0019 * storage capacity in gallons)

= If tank size is unknown, assume 0.600 for a gas storage water heater with a 50-gallon storage capacity and 0.82 for a gas tankless water heater with a 0-gallon storage capacity

EF_{EE} = EF of efficient gas water heater

= Actual or if unknown, assume 0.67 for gas storage water heaters ≤55 gallons, 0.77 for gas storage water heaters >55 gallons and 0.90 for gas tankless water heaters[177]

$EF_{Existing}$ = EF of existing gas water heater

= Actual or if unknown, assume 0.52 [178]

GPD = Gallons per day of hot water use per person

= 17.6[179]

Household = Average number of people per household

Household Unit Type[180]	Household
Single-Family - Deemed	2.67[181]
Multi-Family - Deemed	2.07[182]
Custom	Actual Occupancy or Number of Bedrooms[183]

177 ENERGY STAR Product Specification for Residential Water Heaters, Version 3.0, effective April 16, 2015

178 Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.

179 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. Prepared by Deoreo, B., and P. Mayer for the Water Research Foundation, 2014.

180 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

181 Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, prepared by Cadmus.

182 Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, prepared by Cadmus.

183 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 = Number of 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[184]

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

100,000 = Conversion factor from Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-GWHT-V01-170331

[184] 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

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3.3.4 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, 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.[185]

DEEMED MEASURE COST

The measure cost is the actual cost of material and installation. If actual costs are unknown, assume $58[186] for material and installation.

LOADSHAPE

Flat

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[187]

= 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

185 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).

186 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

187 Area includes tank sides and top to account for typical wrap coverage.

= Actual or if unknown, assume 14[188]

A_{EE} = Surface area (ft^2) of storage tank after addition of tank wrap[189]

= 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 [190]

Hours = Hours per year

= 8,766

ηDHW_{Elec} = Recovery efficiency of electric hot water heater

= Actual or if unknown, assume 0.98 [191]

3,412 = Conversion factor from Btu to kWh

The following table contains default savings for various tank capacities.

Capacity (gal)	A_{Base} (ft^2)[192]	A_{EE} (ft^2)[193]	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

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

Where:

ΔkWh = Electric energy savings, as calculated above.

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

= 0.0000887318[194]

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

[188] 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.

[189] Area includes tank sides and top to account for typical wrap coverage.

[190] Assumes 125°F hot water tank temperature and average basement temperature of 65°F.

[191] Electric water heater recovery efficiency from AHRI database: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

[192] 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.

[193] 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.

[194] 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"

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[195]

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)[196]	A_{EE} (ft^2)[197]	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: RS-HWE-WRAP-V01-170331

[195] 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%.

[196] 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 MO-specific data when available.

[197] A_{EE} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material. Recommend updating with MO-specific data when available.

3.3.5 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, 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.[198]

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a new, electric storage water heater meeting federal minimum efficiency standards[199] 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.[200]

DEEMED MEASURE COST

Actual costs should be used where available. Incremental capital costs are presented in the table below for heat pump water heaters with energy factors (EF) of 2.0 and 2.4.[201]

EF	Rated Volume (gal)	Incremental Cost
2.0	40	$1,340.30
2.4	50	$1,187.58

LOADSHAPE

Residential Electric DHW

Algorithm

CALCULATION OF SAVINGS

[198] Since the federal standard effectively requires a heat pump water heater for units over 55 gallons, this measure is limited to units ≤ 55 gallons.

[199] 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

[200] 2010 Residential Heating Products Final Rule Technical Support Document, U.S. DOE, Table 8.7.2.

[201] Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I_August2016.xls" for more information.

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[202]

Household = Average number of people per household

Household Unit Type[203]	Household
Single-Family - Deemed	2.67[204]
Multi-Family - Deemed	2.07[205]
Custom	Actual Occupancy or Number of Bedrooms[206]

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[207]

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[208]

[202] 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. Prepared by Deoreo, B., and P. Mayer for the Water Research Foundation, 2014.

[203] If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

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

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

[206] 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.

[207] 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

[208] 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.

$$= \left[\frac{\left(\left(1 - \frac{1}{EF_{EE}}\right) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 53\% * LM}{COP_{COOL} * 3{,}412} \right] * \%Cool$$

Where:

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.0 for installation in an unconditioned space

53% = Portion of reduced waste heat that results in cooling savings[209]

COP_{COOL} = COP of central air conditioner

= Actual, or if unknown, assume 2.8 COP[210]

LM = Latent multiplier to account for latent cooling demand

= Dependent on location: [211]

Climate Zone (City based upon)	LM
North East (Fort Madison, IA)	5.1
North West (Lincoln, NE)	3.5
South East (Cape Girardeau, MO)	4.5
South West (Kaiser, MO)	3.7
St Louis, MO	3.0
Kansas City, MO	4.0
Average/Unknown (Knob Noster)	3.2

%Cool = Percentage of homes with central cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91%[212]

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

[209] Based on 193 days where CDD 65>0, divided by 365.25. CDD days determined with a base temp of 65°F.
[210] 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).
[211] 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 is based upon an 8760 analysis of sensible and total heat loads using hourly climate data.
[212] Based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region.xls"

$$= \left(\frac{\left(\left(1 - \frac{1}{EF_{EE}}\right) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 43\%}{COP_{HEAT} * 3{,}412} \right) * \%ElectricHeat$$

Where:

43% = Portion of reduced waste heat that results in increased heating load[213]

COP_{HEAT} = COP of electric heating system

= Actual, or if unknown, assume:[214]

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%[215]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

kWh = Electric energy savings, as calculated above

[213] Based on 157 days where HDD 60>0, divided by 365.25. HDD days determined from Climate Normals data with a base temp of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[214] 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.

[215] 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.

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

= 0.0000887318[216]

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[217]

100,000 = Conversion factor from Btu to therms

ηHeat = Efficiency of heating system

= 71%[218]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[219]

Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-HPWH-V01-170331

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[216] Based on Ameren Missouri 2016 Loadshape for Residential Water Heating End-Use.

[217] 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.

[218] 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.

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

3.3.6 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, 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.[220]

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 [221] per linear foot, including material and installation.

LOADSHAPE

Flat

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

[220] 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).

[221] 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

= Diameter (in) * π/12

= Actual or if unknown, assume 0.131 ft for a pipe with a 0.50 inch diameter

R_{Base} = Thermal resistance coefficient (hr-°F-ft²)/Btu) of uninsulated pipe

= 1.0[222]

C_{EE} = Circumference (ft) of insulated pipe

= Diameter (in) * π/12

= Actual or if unknown, assume 0.524 ft for a 0.50 in diameter pipe insulated with 3/4 in, R-4 wrap ((0.5 + 3/4 + 3/4) * π/12) or 0.654 ft for a 0.50 in diameter pipe insulated with 1 in, R-6 wrap ((0.5 + 1 + 1) * π/12)[223]

R_{EE} = Thermal resistance coefficient (hr-°F-ft²)/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)

= 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 [224]

Hours = Hours per year

= 8,766

ηDHW_{Elec} = Recovery efficiency of electric hot water heater

= Actual or if unknown, assume 0.98 [225]

3,412 = Conversion factor from Btu to kWh

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

= 0.00011415525[226]

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:

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222 "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets," Navigant, April 2009.

223 Pipe wrap thicknesses based on review of available products on Grainger.com

224 Assumes 125°F water leaving the hot water tank and average basement temperature of 65°F.

225 Electric water heater recovery efficiency from AHRI database: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

226 Calculated as 1/8760, consistent with the unitized coincident peak factor approach

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

Where:

ηDHW_{Gas} = Recovery efficiency of gas hot water heater

= 0.78[227]

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: RS-HWE-PINS-V01-170331

[227] 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%.

3.3.7 Thermostatic Restrictor Shower Valve

This measure was not characterized for Version 1 of the Missouri Statewide TRM

3.3.8 Hot Water Measure Kit

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.4 HVAC End Use

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, weather data and forecasts.[228] This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren't yet established at the level of individual features, but rather at the system level and how it performs overall. Like programmable thermostats, it is not suitable to assume that heating and cooling savings follow a similar pattern of usage and savings opportunity, and so here too this measure treats these savings independently. Note that it 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.[229] 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.

Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[230] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default

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

[229] 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'.

[230] This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. It is recommended that program implementations incorporate this data into their planning and operation activities to improve understanding of the measure to manage risks and enhance savings results.

capabilities described above.

DEFINITION OF BASELINE EQUIPMENT

The baseline is either the actual type (manual or programmable) if it is known,[231] or an assumed mix of these two 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[232].

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[233] based upon equipment life only.[234]

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[235], or other program types actual costs are still preferable[236] but if unknown then the average incremental cost for the new installation measure is assumed to be $175[237].

LOADSHAPE

Residential Electric Heating and Cooling

Residential Electric Space Heat

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

232 Value for blend of baseline thermostats comes from an IL 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, p34, April 2013.

233 Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

234 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 only lasted a single year or less, the longer term impacts should be assessed.

235 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.

236 Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.

237 Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $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. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh^{238} = \Delta kWh_{heating} + \Delta kWh_{cooling}$$

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

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

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[239]

$HeatingConsumption_{Electric}$ = Estimate of annual household heating consumption for electrically heated single-family homes[240].

Climate Region (City based upon)	Elec_Heating_ Consumption (kWh)		
	Electric Resistance	Electric Heat Pump	Unknown Electric[241]
North East (Fort Madison, IA)	17,940	10,553	17,017
North West (Lincoln, NE)	19,664	11,567	18,652
South East (Cape Girardeau, MO)	13,502	7,943	12,807
South West (Kaiser, MO)	14,276	8,398	13,541
St Louis, MO	14,144	8,320	13,416
Kansas City, MO	16,272	9,572	15,435
Average/Unknown (Knob Noster)	16,184	9,520	15,351

[238] 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.

[239] 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.

[240] 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 climate region values are calculated using Climate Normals HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions..

[241] Assumption that 12.5% of electrically heated homes in Missouri have Heat Pumps, based on 2009 Residential Energy Consumption Survey for Missouri.

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

Household Type	HF
Single-Family	100%
Multi-Family	65%[242]
Actual	Custom[243]

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

Existing Thermostat Type	Heating_Reduction[244]
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%[245] .

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%[246]

29.3 = kWh per therm

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

Thermostat control of air conditioning?	%AC
Yes	100%
No	0%

[242] Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% reduction factor is applied to MF homes with electric resistance, based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes

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

[244] 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.

[245] 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.

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

Thermostat control of air conditioning?	%AC
Unknown	Actual population data, or 91%[247]

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

= dependent on location[248]:

Climate Region (City based upon)	$EFLH_{cool}$ (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

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[249].

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%[250]

[247] 91% of homes have central cooling in Missouri (based on 2009 Residential Energy Consumption Survey, see "RECS 2009 Air Conditioning_hc7.9.xls").

[248] 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).

[249] Based on Minimum Federal Standard; http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html.

[250] This assumption is based upon the review of many evaluations from other regions in the US. 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

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

Where:

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

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

= 0.0009474181[251]

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%[252]

$HeatingConsumption_{Gas}$

= Estimate of annual household heating consumption for gas heated single-family homes[253].

Climate Region (City based upon)	Gas_Heating_ Consumption (Therms)
North East (Fort Madison, IA)	863
North West (Lincoln, NE)	946
South East (Cape Girardeau, MO)	649
South West (Kaiser, MO)	686
St Louis, MO	680

[251] 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

[252] 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.

[253] 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions. 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 that 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.

Climate Region (City based upon)	Gas_Heating_ Consumption (Therms)
Kansas City, MO	783
Average/Unknown (Knob Noster)	778

Other variables as provided above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ADTH-V01-170331

3.4.2 Air Source Heat Pump

DESCRIPTION

A heat pump provides heating or cooling by moving heat between indoor and outdoor air.

This measure characterizes:

a) Time of Sale:
    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) Early Replacement:
    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 time of sale assumptions.

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

The baseline for the Time of Sale measure is based on the current Federal Standard efficiency level as of January 1st 2015; 14 SEER and 8.2HSPF.

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.[254]

Remaining life of existing ASHP/CAC equipment is assumed to be 6 years[255] and 18 years for electric resistance.

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on the efficiency and capacity of

[254] 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

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

the new unit[256]. Note these costs are per ton of unit capacity:

Efficiency (SEER)	Incremental Cost per Ton of Capacity ($/ton)
15	$170
16	$340
17	$529
18	$710

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume the following (note these costs are per ton of unit capacity)[257]:

Efficiency (SEER)	Full Retrofit Cost (including labor) per Ton of Capacity ($/ton)
15	$2,544
16	$3,120
17	$3,309
18	$3,614

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $2,374 per ton of capacity[258]. This cost should be discounted to present value using the utilities' real discount rate.

LOADSHAPE

Residential Electric Heating and Cooling

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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[259]:

[256] Costs based upon average cost per ton from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. Note SEER 17 and 18 are extrapolated from other data points.

[257] Costs based upon average cost per ton from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.

[258] $2,544 (retrofit cost) - $170 (incremental cost)

[259] 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

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

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

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

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

Where:

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

= dependent on location[260]:

Climate Region (City based upon)	$EFLH_{cool}$ (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

$Capacity_{cool}$ = 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	$SEER_{exist}$[261]
Air Source Heat Pump	7.2
Central AC	6.8
No central cooling[262]	Let ‘$1/SEER_{exist}$’ = 0

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).

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) 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).

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

262 If there is no central cooling in place but the incentive encourages installation of a new ASHP with cooling, the added cooling load should be subtracted from any heating benefit.

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

= 14 [263]

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

= Actual

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

= Dependent on location[264]:

Climate Region (City based upon)	$EFLH_{heat}$ (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

$Capacity_{heat}$ = 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 [265]
Electric Resistance	3.41[266]

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

[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.

[264] 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[265] 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.

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

= 8.2 [267]

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

= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

$\Delta kW = (Capacity_{cool} * (1/EER_{base} - 1/EER_{ee})) / 1000) * CF$

Early replacement[268]:

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

$= ((Capacity_{cool} * (1/EER_{exist} - 1/EER_{ee}))/1000 * CF);$

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

$= ((Capacity_{cool} * (1/EER_{base} - 1/EER_{ee}))/1000 * CF)$

Where:

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

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

$EER\_base = (-0.02 * SEER_{exist}^2) + (1.12 * SEER_{exist})$ [269]

If SEER or EER rating unavailable use:

Existing Cooling System	EER_{exist}[270]
Air Source Heat Pump	6.75
Central AC	6.43
No central cooling[271]	Let '$1/EER_{exist}$' = 0

EER_{base} = Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/hr / kW)

= 11.8 [272]

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[267] 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

[268] 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).

[269] From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

[270] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4, modified to account for degradation. The same methodology used to modify SEER values is applied (78.9% of nameplate). ASHP: 8.55 EER x 78.9% = 6.75, CAC: 8.15 EER x 78.9% = 6.43.

[271] 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.

[272] The Federal Standard does not include an EER requirement, so it is approximated with this formula: (-0.02 * SEER2) + (1.12 * SEER) Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations.

EER_{ee} = Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/hr / kW)

= Actual, If not provided convert SEER to EER using this formula:[273]

$= (-0.02 * SEER_{ee}^2) + (1.12 * SEER_{ee})$

CF = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 67%[274]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ASHP-V01-170331

Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

[273] 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.

[274] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Ameren Illinois, Cadmus, October 2015

3.4.3 Boiler

DESCRIPTION

High-efficiency boilers achieve most gas savings through the use of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gases. Because multiple heat exchangers are used to remove waste heat from the escaping flue gases, some of the flue gases condense and must be drained.

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

a) Time of Sale or New Construction:

The installation of a new, residential sized (<300,000 Btu/hr), high-efficiency, gas-fired hot water boiler in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

The early removal of an existing, functional boiler from service, prior to its natural end of life, and replacement with a new, residential sized (<300,000 Btu/hr), high-efficiency, gas-fired hot water boiler in a residential location. Savings are based on the difference between the existing unit and efficient unit's consumption during the remaining life of the existing unit, and between the new baseline unit and efficient unit's consumption for the remainder of the measure life.

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 new, residential sized (<300,000 Btu/hr), gas-fired hot water boiler with an annual fuel utilization efficiency (AFUE) rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

Time of Sale or New Construction: The baseline equipment is a new, residential sized (<300,000 Btu/hr), gas-fired hot water boiler with an AFUE rating that meets minimum federal energy efficiency standards.

Early Replacement: The baseline is the existing boiler, for the remaining useful life of the unit. For the remainder of the measure life, the baseline is a new boiler with an AFUE rating that meets minimum federal energy efficiency standards.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Time of Sale or New Construction: The expected measure life is assumed to be 26.5 years.[275]

Early Replacement: The remaining life of the existing boiler is assumed to be 9 years.[276]

DEEMED MEASURE COST

The incremental cost for this measure depends on boiler type (hot water or steam) and efficiency, as listed in the table below.[277]

[275] Average lifetime from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers. U.S. Department of Energy, December 22, 2015.
[276] Assumed to be approximately one third of effective useful life.
[277] For boilers with input <300,000 Btu/hr, incremental costs are from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers. U.S. Department of Energy, December 22, 2015.

Incremental Costs for Hot Water Boilers		
Efficiency	Incremental Equipment Cost (Per Unit)	Incremental Total Installed Cost (Per Unit)
83% AFUE	$16	$16
84% AFUE	$31	$31
85% AFUE	$187	$278
90% AFUE	$776	$884
92% AFUE	$1,126	$1,234
96% AFUE	$3,899	$1,924

Incremental Costs for Steam Boilers		
Efficiency	Incremental Equipment Cost (Per Unit)	Incremental Total Installed Cost (Per Unit)
82% AFUE	$40	$64
83% AFUE	$319	$370

LOADSHAPE

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Base}}{AFUE_{Base}}\right)}{100{,}000}$$

Early Replacement:

ΔTherms for remaining life of existing unit (first 9 years):

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Exist}}{AFUE_{Exist}}\right)}{100{,}000}$$

ΔTherms for remaining measure life (next 17.5 years):

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Base}}{AFUE_{Base}}\right)}{100{,}000}$$

Where:

EFLH = Equivalent full load hours for heating

= Dependent on location[278]:

Climate Region (City based upon)	EFLH (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

Capacity = Nominal heating input capacity (Btu/hr) of efficient boiler

= Actual

$AFUE_{EE}$ =Efficiency rating of high efficiency boiler

= Actual

$AFUE_{Base}$ = Efficiency rating of baseline boiler

= 82% AFUE[279]

$AFUE_{Exist}$ = Efficiency rating of existing boiler

= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown, assume 61.6% AFUE.[280]

100,000 = Factor to convert Btus to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-BOIL-V01-170331

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[278] 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions

[279] Federal efficiency standard for hot water, gas-fired residential boilers with input <300,000 Btu/hr from 10 CFR 431.87.

[280] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012).

3.4.4 Duct Sealing

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 types: RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is sealed duct work throughout the unconditioned 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[281].

DEEMED MEASURE COST

The actual duct sealing measure cost should be used.

LOADSHAPE

Residential Electric Heating and Cooling

Residential Electric Space Heat

Residential Cooling

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Modified Blower Door Subtraction

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

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

Where:

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

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

SCF = Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure with respect to the building in the sealed duct system, with the building pressurized to 50 Pascals with resepct to the outside. Use the following look up table provided by Energy Conservatory to determine the appropriate subtraction correction factor:

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

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

b. Calculate duct leakage reduction, convert to $CFM25_{DL}$[282], 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 $CFM25_{DL}$[283]

SLF = Supply Loss Factor[284]

= % leaks sealed located in Supply ducts * 1

Default = 0.5[285]

RLF = Return Loss Factor[286]

= % leaks sealed located in Return ducts * 0.5

Default = 0.25[287]

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

[282] 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions.

[283] 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).

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

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

[286] 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.

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

400 = Conversion of Capacity to CFM (400CFM / ton) [288]

EFLHcool = Equivalent Full Load Cooling Hours

= Dependent on location[289]:

Climate Region (City based upon)	EFLHcool (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

1000 = Converts Btu to kBtu

SEER = Efficiency in SEER of Air Conditioning equipment

= Actual - If not available, use[290]:

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

= Dependent on location[291]:

[288] 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

[289] 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).

[290] 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.

[291] 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

Climate Region (City based upon)	EFLHheat (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

COP = Efficiency in COP of Heating equipment

= Actual - If not available, use[292]:

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%[293]

29.3 = kWh per therm

Methodology 2: Duct Blaster Testing

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

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

---

[292] 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.

[293] 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.

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

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

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[294]

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

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

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

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

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

[294] Savings per unit are based upon analysis performed by Cadmus for the 2011 IA 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.

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

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

= 0.0009474181[295]

NATURAL GAS SAVINGS

<u>For homes with Natural Gas Heating:</u>

<u>Methodology 1: Modified Blower Door Subtraction</u>

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

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)[296]

ηEquipment = Heating Equipment Efficiency

= Actual[297] - If not available, use 83.5%[298]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[299]

= Actual - If not available use 71.0%[300]

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[295] 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

[296] 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 rule-making 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.

[297] The 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.

[298] 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 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.

[299] 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.

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

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[301]

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

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: RS-HVC-DINS-V01-170331

[301] 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.

3.4.5 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.[302]

This measure was developed to be applicable to the following program types: RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

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[303].

DEEMED MEASURE COST

The incremental cost for this measure is provided below:

Unit Size	Incremental Cost[304]
1-Ton	$3,000

[302] The whole purpose of installing ductless heat pumps is to conserve energy, so the installer can be assumed to be capable of recommending an appropriate controls strategy. For most applications, the heating setpoint for the ductless heat pump should be at least 2F higher than any remaining existing system and the cooling setpoint for the ductless heat pump should be at least 2F cooler than the existing system (this should apply to all periods of a programmable schedule, if applicable). This helps ensure that the ductless heat pump will be used to meet as much of the load as possible before the existing system operates to meet the remaining load. Ideally, the new ductless heat pump controls should be set to the current comfort settings, while the existing system setpoints should be adjusted down (heating) and up (cooling) to capture savings.

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

[304] Based on market research and review of online quotes provided by HVAC contractors.

Unit Size	Incremental Cost[304]
1.5-Ton	$3,750
2-Ton	$4,500

LOADSHAPE

Residential Electric Heating and Cooling

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. Dependent on location, see table below

Climate Zone (City based upon)	$EFLH_{heat}$[305]
Cape Girardeau	966
Kaiser	1,004
Knob Noster	1,059
Fort Madison	1,143
Lincoln	1,276
St Louis	1,040
Kansas City	1,174

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

Existing Equipment Type	$HSPF_{exist}$
Electric resistance heating	3.412[306]

305 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 multi-family 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.

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

Existing Equipment Type	$HSPF_{exist}$
Air Source Heat Pump	5.44[307]

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

= Actual installed

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr[308].

= Actual installed

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

= Actual installed[309]

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

= Use actual value. If unknown, see table below

Existing Cooling System	$SEER_{exist}$[310]
Air Source Heat Pump	7.2
Central AC	6.8
Room AC	6.3[311]
No existing cooling[312]	Let '1/SEER_exist' = 0

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. Dependent on location, see table below[313].

307 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.

308 1 Ton = 12 kBtu/hr

309 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.

310 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.

311 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.

312 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.

313 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 multi-family 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.

Climate Zone (City based upon)	$EFLH_{cool}$
Cape Girardeau	509
Kaiser	603
Knob Noster	551
Fort Madison	452
Lincoln	507
St Louis	617
Kansas City	528

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = (Capacity_{cool} * (1/EER_{exist} - 1/EER_{ee}) / 1000) * CF$

Where:

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

= Use actual EER rating otherwise:

Existing Cooling System	EER_{exist}
Air Source Heat Pump	8.55[314]
Central AC	8.15[315]
Room AC	7.7[316]
No existing cooling[317]	Let '1/EER_exist' = 0

EER_{ee} = Energy Efficiency Ratio of new ductless Air Source Heat Pump (kBtu/hr / kW)

= Actual, If not provided convert SEER to EER using this formula: [318]

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

CF = Summer System Peak Coincidence Factor for DMSHP (during system peak hour)

= 43.1%[319]

Other variables as defined above.

NATURAL GAS SAVINGS

N/A

[314] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
[315] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
[316] Same EER as Window AC recycling. Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."
[317] If there is no central cooling in place but the incentive encourages installation of a new DMSHP with cooling, the added cooling load should be subtracted from any heating benefit.
[318] 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.
[319] Based on metering data for 40 DMSHPs in Ameren Illinois service territory, coincident with system peak demand, as outlined in *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015*.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-DHP-V01-170331

3.4.6 Furnace

DESCRIPTION

High-efficiency gas furnaces achieve savings through the use of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, most of the flue gasses condense and must be drained.

This measure was developed to be applicable to the following program type: TOS, NC, EREP:

a) Time of Sale or New Construction:

The installation of a new, residential sized (<225,000 Btu/hr), high-efficiency gas furnace in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

The early removal of an existing, functional furnace from service, prior to its natural end of life, and replacement with a new, residential sized (<225,000 Btu/hr), high-efficiency, gas furnace in a residential location. Savings are based on the difference between the existing unit and efficient unit's consumption during the remaining life of the existing unit, and between the new baseline unit and efficient unit's consumption for the remainder of the measure life.

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 new, residential sized (<225,000 Btu/hr) gas furnace with an annual fuel utilization efficiency (AFUE) rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

Time of Sale or New Construction: The baseline equipment is a new residential sized (<225,000 Btu/hr) gas furnace with an AFUE rating that meets minimum federal energy efficiency standards.

Early Replacement: The baseline is the existing furnace, for the remaining useful life of the unit. For the remainder of the measure life, the baseline is a new furnace with an AFUE rating that meets minimum federal energy efficiency standards.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Time of Sale or New Construction: The expected measure life is assumed to be 19 years.[320]

Early Replacement: The remaining life of the existing furnace is assumed to be 6 years.[321]

[320] Average of 15-year lifetime from Residential Heating and Cooling Systems Initiative Description. Consortium for Energy Efficiency, May 28, 2015 and 23-year lifetime from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces. U.S. Department of Energy, December 15, 2015.

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

DEEMED MEASURE COST

The incremental cost for this measure depends on furnace efficiency, as listed in the table below.[322]

Furance Capacity	Efficiency	Incremental Equipment Cost (Per Unit)	Incremental Total Installed Cost (Per Unit)
<225,000 Btu/hr	90% AFUE	$163.16	$477.93
	92% AFUE	$179.19	$493.96
	95% AFUE	$313.45	$628.22
	98% AFUE	$505.76	$820.53

LOADSHAPE

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Base}}{AFUE_{Base}}\right)}{100{,}000}$$

Early Replacement:

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

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Exist}}{AFUE_{Exist}}\right)}{100{,}000}$$

ΔTherms for remaining measure life (next 13 years):

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Base}}{AFUE_{Base}}\right)}{100{,}000}$$

Where:

322 For furnaces with input <225,000 Btu/hr, incremental costs are from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces. U.S. Department of Energy, February 10, 2015.

EFLH = Equivalent full load hours for heating

= Dependent on location[323]:

Climate Region (City based upon)	EFLH(Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

Capacity = Nominal heating input capacity (Btu/hr) of efficient furnace

= Actual

$AFUE_{EE}$ = Efficiency rating of high efficiency furnace

= Actual

$AFUE_{Base}$ = Efficiency rating of baseline furnace

= 80% AFUE[324]

$AFUE_{Exist}$ = Efficiency rating of existing furnace

= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown, assume 64.4 AFUE%[325]

100,000 = Factor to convert Btus to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-FRNC-V01-170331

323 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

324 Federal standard for furnaces <225,000 Btu/hr from 10 CFR 430.32.

325 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012).

3.4.7 Standard Programmable Thermostat

DESCRIPTION

This measure characterizes the household energy savings from the installation of a new standard programmable thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Because a literature review was not conclusive in providing a defensible source of prescriptive cooling savings from standard programmable thermostats, cooling savings are assumed to be zero for this version of the measure.

Note that the EPA's ENERGY STAR program discontinued its support for standard programmable thermostats effective 12/31/09, and is in the process of developing a new Connected Thermostat specification[326] for this project category which is characterized in the 'Advanced Thermostat' measure.

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, 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[327].

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[328].

LOADSHAPE

Residential Electric Space Heat

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[326] See https://www.energystar.gov/products/spec/connected_thermostats_specification_v1_0_pd

[327] 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.

[328] 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.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh^{329} = (\%ElectricHeat * HeatingConusmption_{Electric} * HF * HeatingReduction * Eff_{ISR} * PF) + (\Delta Therms * Fe * 29.3)$$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[330]

$HeatingConsumption_{Electric}$ = Estimate of annual household heating consumption for electrically heated single-family homes[331].

Climate Region (City based upon)	Elec_Heating_ Consumption (kWh)		
	Electric Resistance	Electric Heat Pump	Unknown Electric[332]
North East (Fort Madison, IA)	17,940	10,553	17,017
North West (Lincoln, NE)	19,664	11,567	18,652
South East (Cape Girardeau, MO)	13,502	7,943	12,807
South West (Kaiser, MO)	14,276	8,398	13,541
St Louis, MO	14,144	8,320	13,416
Kansas City, MO	16,272	9,572	15,435
Average/Unknown (Knob Noster)	16,184	9,520	15,351

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

329 Note the second part of the algorithm relates to furnace fan savings if the heating system is Natural Gas.

330 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.

331 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 climate region values are calculated using the relative Climate Normals HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

332 Assumption that 12.5% of electrically heated homes in Missouri have Heat Pumps, based on 2009 Residential Energy Consumption Survey for Missouri.

family households.

Household Type	HF
Single-Family	100%
Multi-Family	65%[333]
Actual	Custom[334]

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

= 6.8%[335]

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and programmed effectively

Program Delivery	Eff_ISR
Direct Install	100%
Other, or unknown	56%[336]

PF = Persistence Factor to account for thermostat being placed on hold, reset or bypassed.

= Actual if provided in program evaluation, else assume 50% [337]

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%[338]

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333 Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% reduction factor is applied to MF homes with electric resistance, based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes

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

335 The savings from programmable thermostats are highly susceptible to many factors best addressed, so far for this category, by a study that controlled for the most significant issues with a very large sample size. To the extent that the treatment group is representative of the program participants for MO, this value is suitable. Higher and lower values would be justified based upon clear dissimilarities due to program and product attributes. Future evaluation work should assess program specific impacts associated with penetration rates, baseline levels, persistence, and other factors which this value represents.

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

337 This factor is based on consideration of the findings from a number of evaluations, including Sachs et al, *"Field Evaluation of Programmable Thermostats",* US DOE Building Technologies Program, December 2012, p35; "low proportion of households that ended up using thermostat-enabled energy saving settings" http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/field_eval_thermostats.pdf%20, and Meier et al., *"Usability of residential thermostats: Preliminary investigations",* Lawrence Berkeley National Laboratory, March 2011, p1; "The majority of occupants operated thermostats manually, rather than relying on their programmable features and almost 90% of respondents reported that they rarely or never adjusted the thermostat to set a weekend or weekday program. Photographs of thermostats were collected in one on-line survey, which revealed that about 20% of the thermostats displayed the wrong time and that about 50% of the respondents set their programmable thermostats on "long term hold" (or its equivalent)." http://eec.ucdavis.edu/files/Usability_of_residential_thermostats.pdf

338 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%

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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%[339]

$HeatingConsumption_{Gas}$ = Estimate of annual household heating consumption for gas heated single-family homes[340].

Climate Region (City based upon)	Gas_Heating_ Consumption (Therms)
North East (Fort Madison, IA)	863
North West (Lincoln, NE)	946
South East (Cape Girardeau, MO)	649
South West (Kaiser, MO)	686
St Louis, MO	680
Kansas City, MO	783
Average/Unknown (Knob Noster)	778

Other variables as provided above.

F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

339 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.

340 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 Normals HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions. 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 that 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.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-PROG-V01-170331

3.4.8 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 types: 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[341].

DEEMED MEASURE COST

As a retrofit measure, actual costs should be used. If unavailable, the measure cost should be assumed to be $175[342].

LOADSHAPE

Residential Central Cooling

Residential Electric Heat

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[343]:

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

[342] 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.

[343] 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).

Climate Region (City based upon)	$EFLH_{cool}$ (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

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

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

$SEER_{test-in}$ = 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[344]:

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

When unknown[345], 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[346]:

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

When unknown[347], assume SEER = 13.6

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

= Dependent on location[348]:

344 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.

345 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."

346 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.

347 Using aforementioned relationship and test-in efficiency of 11.56 EER, as listed in "Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015."

348 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 Climate Normals Heating Degree Day ratios (at 60F set point). NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

Climate Region (City based upon)	$EFLH_{heat}$ (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

$Capacity_{heat}$ = 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[349] 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[350] HSPF = 6.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (Capacity_{cool} * (1/EER_{test-in} - 1/EER_{test-out})) / 1000) * CF$$

Where:

$EER_{test-in}$ = EER Efficiency of existing unit before tuning (Btu/H/Watts). In most instances, test-in EER will be determined and noted prior to tuning, however if unknown, assume[351] 10.50.

$EER_{test-in}$ = EER Efficiency of existing unit after tuning (Btu/H/Watts). In most instances, test-out EER will be determined and noted after tuning, however if unknown, assume[352] 11.56.

CF = Summer System Peak Coincidence Factor. Dependent of whether the unit is an air conditioner or air source heat pump. For Central A/C, use CF = 73.9%[353], for air source heat pump, use CF = 67%[354]

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

[350] 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."

[351] As reported in "Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015."

[352] As reported in "Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015."

[353] Based on the Ameren Missouri Heating and Cooling Program Impact and Process Evaluation for PY15.

[354] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Ameren Illinois, Cadmus, October 2015

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-TUNE-V01-170331

3.4.9 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, 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[355].

DEEMED MEASURE COST

The capital cost for this measure is assumed to be $97[356].

LOADSHAPE

Residential Cooling

Residential Electric Space Heat

Residential Electric Heating and Cooling

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \text{Heating Savings} + \text{Cooling Savings} + \text{Shoulder Season Savings}$$

Where:

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[355] 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

[356] 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

Heating Savings = Blower motor savings during heating season

= 430 kWh[357]

Cooling Savings = Blower motor savings during cooling season

If Central AC = 159 kWh

If No Central AC = 107 kWh

If unknown (weighted average)

= 152 kWh[358]

Shoulder Season Savings = Blower motor savings during shoulder seasons

= 69 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Cooling Savings * CF

Where:

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

= 0.0009474181[359]

Using defaults (unknown cooling savings):

ΔkWh = 430 + 152 + 69

= 651 kWh

ΔkW = 152 * 0.0009474181

= 0.1440 kW

NATURAL GAS SAVINGS

Δtherms[360] = - Heating Savings * 0.03412/ AFUE

Where:

0.03412 = Converts kWh to therms

AFUE = Efficiency of the Furnace

= Actual. If unknown assume 95%[361] if in new furnace or 64.4 AFUE%[362] if in existing furnace

Using defaults:

[357] To estimate heating, cooling and shoulder season savings for Missouri, savings are adapted using results from a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin. This study included effects of behavior change based on the efficiency of new motor greatly increasing the amount of people that run the fan continuously. The savings from the Wisconsin study were adjusted on a total savings ratio to that reported in the Ameren Missouri Heating and Cooling Program Impact and Process Evaluation: Program Year 2015. See: "FOE to MO Blower Savings.xlsx".

[358] The weighted average value is based on 2009 RECS data that 87% of MO homes use CAC equipment.

[359] 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

[360] 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.

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

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

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: RS-HVC-FBMT-V01-170331

3.4.10 Central Air Conditioner

DESCRIPTION

This measure characterizes:

a) Time of Sale:

   a. The installation of a new residential sized (<= 65,000 Btu/hr) Central Air Conditioning ducted split system meeting ENERGY STAR efficiency standards presented below. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

Early Replacement determination will be defined by program requirements.All other conditions will be considered Time of Sale.

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

- If the SEER of the existing unit is known and, the Baseline SEER is the actual SEER value of the unit replaced. f the SEER of the existing unit is unknown, use assumptions in variable list below (SEER_exist).

A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown[363].

Deemed Early Replacement Rates For CAC Units in Combined System Replacement (CSR) Projects

Replacement Scenario for the CAC Unit	Deemed Early Replacement Rate
Early Replacement Rate for a CAC unit when the CAC unit is the Primary unit in a CSR project	14%
Early Replacement Rate for a CAC unit when the CAC unit is the Secondary unit in a CSR project	40%

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a ducted split central air conditioning unit meeting the minimum ENERGY STAR efficiency level standards; 15 SEER and 12 EER.

DEFINITION OF BASELINE EQUIPMENT

The baseline for the Time of Sale measure is based on the current Federal Standard efficiency level; 13 SEER and 11 EER.

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

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[364] for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years[365].

Remaining life of existing equipment is assumed to be 6 years[366].

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below[367]:

Efficiency Level	Cost per Ton
SEER 14	$119
SEER 15	$238
SEER 16	$357
SEER 17	$476
SEER 18	$596
SEER 19	$715
SEER 20	$834
SEER 21	$908
Average	$530

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[368].

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $3,140[369]. This cost should be discounted to present value using the utilities' discount rate.

LOADSHAPE

Loadshape - Residential Central Cooling

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364 Baseline SEER and EER should be updated when new minimum federal standards become effective.

365 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).

366 Assumed to be one third of effective useful life

367 DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com)

368 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).

369 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.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

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

Early replacement[370]:

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

= Dependent on location[371]:

Climate Region (City based upon)	EFLHcool (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

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[372]

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

= 13[373]

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

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370 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).

371 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).

372 Actual unit size required for multi-family building, no size assumption provided because the unit size and resulting savings can vary greatly depending on the number of units.

373 Based on Minimum Federal Standard; http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html.

= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 10.0[374].

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

= Actual installed or 14.5 if unknown

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

ΔkW = (Capacity * (1/EERbase - 1/EERee))/1000 * CF

Early replacement[375]:

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

= ((Capacity * (1/EERexist - 1/EERee))/1000 * CF);

ΔkW for remaining measure life (next 12 years):

= ((Capacity * (1/EERbase - 1/EERee))/1000 * CF)

Where:

EERbase = EER Efficiency of baseline unit

= 11.2 [376]

EERexist = EER Efficiency of existing unit

= Actual EER of unit should be used, if EER is unknown, use 9.2[377]

EERee = EER Efficiency of ENERGY STAR unit

= Actual installed or 12 if unknown

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

= 73.9%[378]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

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374 Estimate based on Department of Energy Federal 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.

375 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).

376 The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (13) and equals EER 11.2. To perform this calculation we are using this formula: (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).

377 Based on SEER of 10.0, using formula above to give 9.2 EER.

378 Based on the Ameren Missouri Heating and Cooling Program Impact and Process Evaluation for PY15.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-CAC1-V01-170331

3.4.11 Filter Cleaning or Replacement

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 types: 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[379].

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[380], 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.

LOADSHAPE

Residential Electric Heating

Algorithm

CALCULATION OF SAVINGS

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

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (kW_{old\ filter} - kW_{new\ filter}) * Hours_{heating\ season}$$

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379 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.

380 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:

$kW_{old\ filter}$ = $Q_{CFMold} * P_{Dold} / (6345 * \eta_{fan}) * 0.7457$

$kW_{new\ filter}$ = $Q_{CFMnew} * P_{Dnew} / (6345 * \eta_{fan}) * 0.7457$

Q_{CFMold} = Airflow across filter of the existing system, in CFM

= Actual, otherwise assume[381] 835.1 CFM.

Q_{CFMnew} = New airflow[382] across new filter, in CFM

= Actual, otherwise assume[383] 927.9 CFM.

P_{Dold} = Pressure drop across the existing filter, in inches of water.

= Actual, otherwise assume[384] 0.2

P_{Dnew} = Pressure drop across the new filter, in inches of water.

= Actual, otherwise assume[385] 0.1

6345 = combined factor consisting of 33,013 (converts ft-lbs/minute to horsepower) divided by 5.202 (converts inches of water to lbs/ft^2)

η_{fan} = efficiency of the complete fan system, including motor efficiency and the mechanical efficiency of the fan.

= Actual, if unknown assume 45.5%[386]

0.7457 = converts horsepower to kW

$Hours_{heating\ season}$ = Annual hours the blower is expected to operate during the heating season

= Actual, if unknown assume[387] 3,258 hours.

Using the above defaults results in savings of 62.5 kWh.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer coincident peak demand savings are claimed for this measure as, savings occur during the heating season.

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[381] A 10% reduction of Q_{CFMNew}. Estimated using a typical residential fan curve as outlined in "The Effects of Filtration on Pressure Drop and Energy Consumption in Residential HVAC Systems (RP-1299)" ASHRAE, Stephens et al., given the assumed differences in pressure drop across filters and the total average system pressure drop of 0.9 as suggested by "EFFICIENCY CHARACTERISTICS AND OPPORTUNITIES FOR NEW CALIFORNIA HOMES (ECO)" Prepared for the California Energy Commission, March 2011.

[382] It is assumed that the majority of forced air systems are not capable of speed controls to modulate airflow, thus a decrease in pressure drop will result in increased flow.

[383] Average flow rate observed in residential heating applications, outlined in "Evaluation of Retrofit Variable-Speed Furnace Fan Motors" R. Aldrich and J. Williamson, Consortium for Advanced Residential Buildings, January 2014

[384] Based on an industry rule of thumb that filters be replaced when the pressure drop across them has doubled. THE ENERGY & FILTER FACT HANDBOOK, 2014 Camfil, USA.

[385] ACCA Manual D suggests that a standard filter, when clean, will typically have a pressure drop of 0.1 IWC across it.

[386] Mechanical efficiency of fan assumed to be 65%, based on typical fan curve and motor efficiency assumed to be 70%, as suggested by "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment" US Department of Energy, Building Technologies Office, December 2013. Combined, overall fan efficiency is therefore 45.5%.

[387] Accounting for cycling, assumes the fan will operate 75% of the time during the heating season, estimated to be 4,344 hours total.

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-FILT-V01-170331

3.4.12 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, EREP.

This measure characterizes:

a) Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.

b) Early Replacement: 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

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

Early Replacement: 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[388].

Remaining life of existing equipment is assumed to be 5 years[389].

DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this equipment is estimated to be $84/ton.[390]

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unknown assume $1,047 per ton[391].

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

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

[390] DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation.

[391] Based on DCEO – IL PHA Efficient Living Program data.

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton[392]. This cost should be discounted to present value using the utilities' discount rate.

LOADSHAPE

Residential Electric Heating and Cooling

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[393]:

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 dependent on location, per the following table:

Climate Zone (City based upon)	$EFLH_{heat}$[394]
Cape Girardeau	966
Kaiser	1,004

392 Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

393 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).

394 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 multi-family 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.

Climate Zone (City based upon)	$EFLH_{heat}$ [394]
Knob Noster	1,059
Fort Madison	1,143
Lincoln	1,276
St Louis	1,040
Kansas City	1,174

$HSPF_{ee}$ = 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[395]
PTHP	5.44[396]

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr[397].

= Actual installed

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

= Actual installed[398]

$SEER_{base}$ = 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

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

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

396 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.

397 1 Ton = 12 kBtu/hr

398 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.

Existing Cooling System	$SEER_{exist}$[399]
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 dependent on location, per the following table[400].

Climate Zone (City based upon)	$EFLH_{cool}$
Cape Girardeau	509
Kaiser	603
Knob Noster	551
Fort Madison	452
Lincoln	507
St Louis	617

Summer Coincident Peak Demand Savings

Time of sale:

$\Delta kW = (Capacity_{cool} * (1/EER_{base} - 1/EER_{ee})) / 1000) * CF$

Early replacement[401]:

ΔkW for remaining life of existing:

$= ((Capacity_{cool} * (1/EER_{exist} - 1/EER_{ee}))/1000 * CF);$

ΔkW for remaining measure life:

$= ((Capacity_{cool} * (1/EER_{base} - 1/EER_{ee}))/1000 * CF)$

Where:

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

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

399 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.

400 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 multi-family 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.

401 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).

EER unknown but SEER available convert using the equation:

$EER\_base = (-0.02 * SEER_{exist}^2) + (1.12 * SEER_{exist})$ [402]

If SEER or EER rating unavailable use:

Existing Cooling System	EER_{exist}[403]
PTHP	6.75
PTAC	6.43

EER_{base} = Energy Efficiency Ratio of baseline unit (kBtu/hr / kW) [404]

Equipment Type	EER_{base} (manufacture date prior to 1/2/2017)	EER_{base} (manufacture date after to 1/1/2017)
PTAC	11.2	11.8
PTHP	11.2	11.8

EER_{ee} = Energy Efficiency Ratio of efficient unit (kBtu/hr / kW)

= Actual, If not provided convert SEER to EER using this formula:[405]

$= (-0.02 * SEER_{ee}^2) + (1.12 * SEER_{ee})$

CF = Summer System Peak Coincidence Factor (during system peak hour)

= 43.1%[406]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PTAC-V01-170331

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402 From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

403 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4, modified to account for degradation. The same methodology used to modify SEER values is applied (78.9% of nameplate). ASHP: 8.55 EER x 78.9% = 6.75, CAC: 8.15 EER x 78.9% = 6.43.

404 The Federal Standard does not include an EER requirement, so it is approximated with this formula: (-0.02 * SEER^2) + (1.12 * SEER) Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

405 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.

406 Based on metering data for 40 DMSHPs in Ameren Illinois service territory, coincident with system peak demand, as outlined in *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015*.

3.4.13 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:[407]

<table>
<tr><th>Product Class (Btu/H)</th><th>Federal Standard CEERbase, with louvered sides, without reverse cycle[408]</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[409]	ENERGY STAR CEERee, with louvered sides[410]	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

[407] 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

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

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

[410] 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.

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

Definition of Efficient Equipment

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.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 9 years.[411]

Deemed Measure Cost

The incremental cost for this measure is assumed to be $50 for an ENERGY STAR unit.[412]

Loadshape

Residential Cooling

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

= dependent on location:

Climate Zone (City based upon)	Hours[413]
North East (Fort Madison, IA)	406
North West (Lincoln, NE)	397
South East (Cape Girardeau, MO)	491
South West (Kaiser, MO)	454

[411] Energy Star Room Air Conditioner Savings Calculator, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=AC

[412] Energy Star Room Air Conditioner Savings Calculator, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=AC

[413] The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008: 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 CDD to provide an assumption for FLH for Room AC.

Climate Zone (City based upon)	Hours[413]
St Louis, MO	556
Kansas City, MO	460
Average/Unknown (Knob Noster)	432

Btu/H = Size of unit

= Actual. If unknown assume 8500 Btu/hr [414]

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[415]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RMAC-V01-170331

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

[415] Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use

3.4.14 Fireplace

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.4.15 Furnace/Boiler Tune-Up

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.4.16 Ground Source Heat Pump

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.4.17 Heat Pump Resistance Heat Lockout

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.4.18 Integrated Space and Water Heater

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.4.19 Single-Package and Split System Unitary Air Conditioner

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.5 Lighting End Use

3.5.1 Compact Fluorescent Lamp

DESCRIPTION

A low wattage compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb.

This characterization provides assumptions for when the CFL 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 assumption is provided. 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 essence making the baseline equivalent to a current day CFL. Therefore, the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb, when added to the year of installation, exceeds 2020.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a standard general service compact fluorescent lamp. Note as of 1/2/2017, ENERGY STAR specification v2.0 becomes effective, (https://www.energystar.gov/sites/default/files/Luminaires%20V2%200%20Final.pdf) and currently no CFL can meet the v2.0 requirements (and manufacturers are indicating that they are not planning to re-engineer CFLs to meet the new spec). In order to ensure the quality of product being supported by efficiency programs, an archived list of CFLs that met the previous ENERGY STAR standard will remain available and it is recommended this be the standard used for supporting non-ENERGY STAR bulbs going forward

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an EISA qualified halogen or incandescent lamp.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

For Residential, Multifamily In-unit bulbs, and Unknown: The expected lifetime of a CFL is assumed to be 5.2 years[416]. To account for the backstop provision of the EISA 2007 legislation, the lifetime should be capped to the number of years until 2020 due to the EISA backstop provision.

DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for all bulbs is $0.40 (baseline cost of

[416] Jump et al. 2008: "Welcome to the Dark Side: The Effect of Switching on CFL Measure Life" indicates that the "observed life" of CFLs with an average rated life of 8000 hours (8000 hours is the average rated life of ENERGY STAR bulbs (http://www.energystar.gov/index.cfm?c=cfls.pr_crit_cfls) is 5.2 years.

$1.80 and efficient cost of $2.20[417]).

For the Direct Install measure, actual program delivery costs should be used if available. If not, the full cost of $2.20 per bulb should be used, plus $6.25 labor[418], for a total measure cost of $8.45 per bulb.

For bulbs provided in Efficiency Kits, the actual program delivery costs should be used.

LOADSHAPE

Residential Indoor Lighting

Residential Outdoor Lighting

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * (WHFeHeat + (WHFeCool - 1))$$

Where:

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

$Watts_{EE}$ = Actual wattage of CFL purchased / installed - If unknown, assume the following defaults[419]:

Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$ CFL	Delta Watts
250	309	25	5.1	19.9
310	749	29	9.4	19.6
750	1,049	43	13.4	29.6
1,050	1,489	53	18.9	34.1
1,490	2,600	72	24.8	47.2
2,601	3,000	150	41.1	108.9
3,001	3,999	200	53.8	146.2
4,000	6,000	300	65.0	235

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

[417] Incandescent/halogen and CFL cost assumptions based on Cadmus “LED Incremental Cost Study: Overall Final Report”, February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p19. Note CFL cost is an average of standard spiral and covered A-lamps.

[418] Assumption 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.

[419] $Watts_{EE}$ defaults are based upon the average available ENERGY STAR v1.0 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.

Program	Discounted In Service Rate (ISR)
Retail (Time of Sale)[420]	98%
Direct Install[421]	96%
Efficiency Kit (Single Family)[422]	75%
Efficiency Kit (Multi-Family)[423]	98%

Hours = Average hours of use per year

= Custom, or if unknown assume 728[424] for interior or 1314 for exterior, or 776 if location is not known.

$WHFe_{Heat}$ = 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)

$= 1 - ((HF / \eta Heat_{Electric}) * \%ElecHeat)$

If unknown assume 0.88[425]

Where:

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

= 53%[426] 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[427]:

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

420 Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate).

421 Ameren Missouri Home Energy Analysis Program Impact and Process Evaluation: Program Year 2015

422 Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015

423 Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015

424 Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. Average daily HOU for efficient bulbs is listed as 3.6 for outside bulbs and a weighted (by inventory) average of 1.99 for inside spaces. Unknown location is weighted average (by inventory) of all bulbs. See 'MO Lamp Hours.xls' for calculations.

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

426 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). Result judged to be equally applicable to Missouri.

427 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 Estimate	ηHeat (COP Estimate)
Unknown	N/A	N/A	1.57[428]

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[429]

$WHFe_{Cool}$ = 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[430]
Building without cooling or exterior	1.0
Unknown	1.11[431]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * \mathrm{WHF_{eCool}} * CF$$

Where:

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

Bulb Location	CF
Residential Interior and in-unit Multifamily [432]	0.0001492529
Exterior [433]	0.0
Unknown (e.g., Retail, Upstream and Efficiency Kits)[434]	0.0001417903

428 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.

429 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.

430 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). 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)), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm ($-0.02 * SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP). Result assumed to be applicable to Missouri.

431 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").

432 Based on Ameren Missouri 2016 Loadshape for Residential Lighting End-Use

433 Outdoor lighting should not be assumed operational during the defined summer peak hour.

434 Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.

Other factors as defined above.

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes[435]:

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

Where:

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

= 53%[436] 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%[437]

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

Heating fuel	%GasHeat
Electric	0%
Natural Gas	100%
Unknown	65%[438]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

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

Installation Location	Replacement Period (years)[439]	Replacement Cost
Residential Interior and in-unit	1.4	

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435 Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

436 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). Result judged to be equally applicable to Missouri.

437 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.

438 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.

439 Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescent is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than

Installation Location	Replacement Period (years)[439]	Replacement Cost
Multifamily		$1.80[440]
Exterior	0.8	
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1.3	

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Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

440 Incandescent/halogen cost assumptions based on Cadmus “LED Incremental Cost Study: Overall Final Report”, February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p19.

3.5.2 LED Screw Based Omnidirectional Bulb

Description

This characterization provides savings assumptions for LED Screw Based Omnidirectional (e.g., A-Type) lamps. This characterization provides assumptions for LEDs 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 assumption is provided. 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 essence 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, 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 will become 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[441].

Definition of Baseline Equipment

The baseline condition for this measure is assumed to be an EISA qualified halogen or incandescent. From 2020 the baseline becomes a CFL[442] and therefore a midlife adjustment is provided.

Deemed Lifetime of Efficient Equipment

The rated life of omnidirectional LED lamps is assumed to be 20,000[443]. This would imply a lifetime of 27 years for Residential interior and 15.2 years for Residential exterior; however, all installations are capped at 19 years[444].

Deemed Measure Cost

Wherever possible, actual incremental costs should be used. If unavailable, assume $3.26 (baseline cost of

441 https://www.designlights.org/QPL

442 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.

443 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.

444 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.

$1.80 and efficient cost of $5.06[445]).

LOADSHAPE

Residential Indoor Lighting

Residential Outdoor Lighting

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * (WHFeHeat + (WHFeCool - 1))$$

Where:

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

$Watts_{EE}$ = Actual wattage of LED purchased / installed - If unknown, use default provided below[446]:

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

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

Program	Discounted In Service Rate (ISR)
Retail (Time of Sale)[447]	98%

[445] Incandescent/halogen and LED cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report", February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p19.

[446] $Watts_{EE}$ 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.

[447] Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate).

Program	Discounted In Service Rate (ISR)
Direct Install[448]	99%
Efficiency Kit (Single Family)[449]	92%
Efficiency Kit (Multi-Family)[450]	98%

Hours = Average hours of use per year

= Custom, or if unknown assume 728[451] for interior or 1314 for exterior, or 776 if location is not known.

$WHFe_{Heat}$ = 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[452]

Where:

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

= 53%[453] 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[454]:

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[455]

448 Ameren Missouri Home Energy Analysis Program Impact and Process Evaluation: Program Year 2015

449 Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015

450 Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015

451 Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. Average daily HOU for efficient bulbs is listed as 3.6 for outside bulbs and a weighted (by inventory) average of 1.99 for inside spaces. Unknown location is weighted average (by inventory) of all bulbs. See 'MO Lamp Hours.xls' for calculations.

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

453 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). Result judged to be equally applicable to Missouri.

454 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.

455 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.

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[456]

$WHFe_{Cool}$ = 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[457]
Building without cooling or exterior	1.0
Unknown	1.11[458]

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 in 2020 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, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

Lower Lumen Range	Upper Lumen Range	Mid Lumen Range	WattsEE	WattsBase before EISA 2020	Delta Watts before EISA 2020	WattsBase after EISA 2020[459]	Delta Watts after EISA 2020	Mid Life adjustment (in 2020) to first year savings
250	309	280	4.0	25	21	25	21.0	100.0%
310	749	530	6.7	29	22.3	9.4	2.7	12.1%
750	1049	900	10.1	43	32.9	13.4	3.3	10.0%
1050	1489	1270	12.8	53	40.2	18.9	6.1	15.2%
1490	2600	2045	17.4	72	54.6	24.8	7.4	13.6%
2,601	3,000	2,775	43.1	150	106.9	150	106.9	100.0%
3,001	3,999	3,500	53.8	200	146.2	200	146.2	100.0%

[456] 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.
[457] The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). 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)), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm ($-0.02 * SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP). Result assumed to be applicable to Missouri.
[458] 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").
[459] Calculated with EISA requirement of 45lumens/watt.

Lower Lumen Range	Upper Lumen Range	Mid Lumen Range	WattsEE	WattsBase before EISA 2020	Delta Watts before EISA 2020	WattsBase after EISA 2020[459]	Delta Watts after EISA 2020	Mid Life adjustment (in 2020) to first year savings
4,000	6,000	5,000	76.9	300	223.1	300	223.1	100.0%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * \mathrm{WHF_{eCool}} * CF$$

Where:

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

Bulb Location	CF
Residential Interior and in-unit Multifamily [460]	0.0001492529
Exterior [461]	0.0
Unknown (e.g., Retail, Upstream and Efficiency Kits)[462]	0.0001417903

Other factors as defined above.

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes[463]:

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

Where:

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

= 53%[464] 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%[465]

[460] Based on Ameren Missouri 2016 Loadshape for Residential Lighting End-Use
[461]Outdoor lighting should not be assumed operational during the defined summer peak hour.
[462] Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.
[463] Negative value because this is an increase in heating consumption due to the efficient lighting.
[464] 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). Result judged to be equally applicable to Missouri.
[465] 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

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

Heating fuel	%GasHeat
Electric	0%
Natural Gas	100%
Unknown	65%[466]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

In order to account for the shift in baseline due to the backstop provision of the Energy Independence and Security Act of 2007, requiring all standard bulbs (except for <310 and 2600+ lumen lamps) to have an efficacy equivalent to today's CFL, an annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. Bulb replacement costs assumed in the O&M calculations are provided below[467].

Incandescent / Halogen,	CFL	LED A-Lamp
$1.80	$2.20	$5.06

The present value of replacement lamps and annual levelized replacement costs using utilities' average real discount rate of 6.91% are presented below[468]:

Location	PV of replacement costs for period			Levelized annual replacement cost savings		
	2016 - 2017	2017 - 2018	2018 - 2019	2016 - 2017	2017 - 2018	2018 - 2019
Residential and in-unit Multifamily	$4.72	$3.77	$2.74	$0.45	$0.36	$0.26
Exterior	$8.00	$6.30	$4.48	$0.87	$0.69	$0.49
Unknown	$4.91	$3.91	$2.85	$0.47	$0.38	$0.27

Note: incandescent lamps in lumen range <310 and >2600 are exempt from EISA. For these bulb types, an O&M cost should be applied as follows:

Installation Location	Replacement Period (years)[469]	Replacement Cost
Residential Interior and in-unit	1.4	

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.

466 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.

467 All cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report", February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p19.

468 See "Proposed LED Assumptions.xls" for more information. Average discount rate based on: Laclede (7.19%), KCP&L (6.5841%) and Ameren (6.95%).

469 Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/

Installation Location	Replacement Period (years)[469]	Replacement Cost
Multifamily		$1.80[470]
Exterior	0.8	
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1.3	

MEASURE CODE: RS-LTG-LEDA-V01-170331

Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

[470] Incandescent/halogen cost assumptions based on Cadmus "LED Incremental Cost Study: Overall Final Report", February 2016 (http://ma-eeac.org/wordpress/wp-content/uploads/MA-Task-5b-LED-Incremental-Cost-Study_FINAL_01FEB2016.pdf), p19.

3.5.3 LED Specialty Lamp

DESCRIPTION

This characterization provides savings assumptions for LED Directional, Decorative, and Globe lamps. This characterization provides assumptions for 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 assumption is provided. 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 essence making the baseline equivalent to a current day CFL.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new lamps must be ENERGY STAR labeled based upon the ENERGY STAR specification v2.0 which will become 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.[471]

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an EISA qualified halogen or incandescent.

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[472]. 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.[473]

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs[474]:

[471] https://www.designlights.org/QPL

[472] ENERGY STAR, v2.0; https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20AUG-2016.pdf)

[473] 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.

[474] Incandescent based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year's worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; "Energy Savings Potential of Solid-State Lighting in General Illumination Applications", Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

Bulb Type	LED Wattage	LED	Incandescent	Incremental Cost
Directional	< 20W	$14.52	$6.31	$8.21
	≥20W	$45.85		$39.54
Decorative	<15W	$8.09	$3.92	$4.17
	15 to <25W	$15.86		$11.94
	≥25W	$15.86		$11.94

LOADSHAPE

Residential Indoor Lighting

Residential Outdoor Lighting

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * Hours * (WHFeHeat + (WHFeCool - 1))$$

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[475]:

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

[475] $Watts_{EE}$ 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.

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$	$Watts_{EE}$	Delta Watts
	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

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

Program	Discounted In Service Rate (ISR)
Retail (Time of Sale)[476]	98%
Direct Install[477]	99%
Efficiency Kit (Single Family)[478]	92%
Efficiency Kit (Multi-Family)[479]	98%

Hours = Average hours of use per year

= Custom, or if unknown assume 728[480] for interior or 1,314 for exterior, or 776 if location is not known.

$WHFe_{Heat}$ = 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[481]

Where:

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

[476] Based on results presented in Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. This value takes into account the time-delay of when bulbs are installed over subsequent program years. The reported ISR is based on the net present value (NPV) of the savings over 4 year installation period from the PY15 bulbs, discounted back to Year 1 at 6.95% (utility discount rate).

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

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

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

[480] Ameren Missouri Lighting Impact and Process Evaluation: Program Year 2015. Average daily HOU for efficient bulbs is listed as 3.6 for outside bulbs and a weighted (by inventory) average of 1.99 for inside spaces. Unknown location is weighted average (by inventory) of all bulbs. See 'MO Lamp Hours.xls' for calculations.

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

= 53%[482] 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[483]:

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[484]

%ElecHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[485]

$WHFe_{Cool}$ = 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[486]
Building without cooling or exterior	1.0
Unknown	1.11[487]

482 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). Result judged to be equally applicable to Missouri.

483 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.

484 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.

485 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.

486 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). 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)), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER^2) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP). Result assumed to be applicable to Missouri.

487 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").

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * WHFeCool * CF$$

Where:

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

Bulb Location	CF
Residential Interior and in-unit Multifamily [488]	0.0001492529
Exterior [489]	0.0
Unknown (e.g., Retail, Upstream and Efficiency Kits)[490]	0.0001417903

Other factors as defined above.

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes[491]:

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

Where:

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

= 53%[492] 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%[493]

%GasHeat = Percentage of homes with gas heat

[488] Based on Ameren Missouri 2016 Loadshape for Residential Lighting End-Use

[489] Outdoor lighting should not be assumed operational during the defined summer peak hour.

[490] Assumes 5% exterior lighting, based on PY5/PY6 ComEd Residential Lighting Program evaluation.

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

[492] 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, IA. Result judged to be equally applicable to Missouri.

[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)). 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.

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	65%[494]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M cost should be applied as follows:

Installation Location	Replacement Period (years)[495]	Replacement Cost[496]
Residential Interior and in-unit Multifamily	1.4	Decorative: $6.31
Exterior	0.8	
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1.3	Directional: $3.92

MEASURE CODE: RS-LTG-LEDS-V01-170331

[494] 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.

[495] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

[496] Incandescent costs based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.

3.6 Motors End Use

3.6.1 Pool Pump

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.7 Shell End Use

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[497]. 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 types: RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be 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.[498]

DEEMED MEASURE COST

The actual capital cost for this measure should be used.

LOADSHAPE

Residential Cooling

Residential Central Heat

Residential Heat Pump

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Test In / Test Out Approach

$$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$$

[497] Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.
[498] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

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[499]

$CFM50_{Post}$ = Infiltration at 50 Pascals as measured by blower door after air sealing

= Actual

N_{cool} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

=Dependent on location and number of stories:[500]

Climate Zone (City based upon)	N_cool (by # of stories)			
	1	1.5	2	3
North East (Fort Madison, IA)	43.0	38.1	35.0	31.0
North West (Lincoln, NE)	30.3	26.9	24.6	21.8
South East (Cape Girardeau, MO)	40.9	36.2	33.2	29.4
South West (Kaiser, MO)	41.2	36.5	33.4	29.6
St Louis, MO	34.9	30.9	28.3	25.1
Kansas City, MO	31.3	27.7	25.4	22.5
Average/Unknown (Knob Noster)	35.5	31.4	28.8	25.5

60 * 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

= Dependent on location[501]:

Climate Zone (City based upon)	CDD 65
North East (Fort Madison, IA)	1200
North West (Lincoln, NE)	1174
South East (Cape Girardeau,	1453

499 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 and adjust your 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.

500 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.

501 Based on Climate Normals data with a base temperature of 65°F.

Climate Zone (City based upon)	CDD 65
MO)	
South West (Kaiser, MO)	1344
St Louis, MO	1646
Kansas City, MO	1360
Average/Unknown (Knob Noster)	1278

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [502]

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[503]:

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

= dependent on location: [504]

Climate Zone (City based upon)	LM
North East (Fort Madison, IA)	5.1
North West (Lincoln, NE)	3.5
South East (Cape Girardeau, MO)	4.5
South West (Kaiser, MO)	3.7
St Louis, MO	3.0
Kansas City, MO	4.0
Average/Unknown (Knob Noster)	3.2

502 This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

503 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.

504 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 is based upon an 8760 analysis of sensible and total heat loads using hourly climate data.

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 location and building height:[505]

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
North East (Fort Madison, IA)	24.9	22.1	20.2	17.9
North West (Lincoln, NE)	23.0	20.4	18.7	16.6
South East (Cape Girardeau, MO)	25.7	22.8	20.9	18.5
South West (Kaiser, MO)	26.6	23.6	21.6	19.2
St Louis, MO	24.0	21.3	19.5	17.3
Kansas City, MO	22.6	20.0	18.4	16.3
Average/Unknown (Knob Noster)	23.8	21.1	19.3	17.1

HDD = Heating Degree Days

= Dependent on location:[506]

Climate Zone (City based upon)	HDD 60
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	3528
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037

[505] 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.

[506] The calculations made in this measure have been based on using Climate Normals data 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

ηHeat = Efficiency of heating system

= Actual - If not available refer to default table below[507]:

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

<u>Conservative Deemed Approach</u>

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[508]

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

[507] 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.

[508] 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 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%[509]

29.3 = kWh per therm

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[510]

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 location and building height:[511]

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
North East (Fort Madison, IA)	24.9	22.1	20.2	17.9
North West (Lincoln, NE)	23.0	20.4	18.7	16.6

509 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.

510 Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

511 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.

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
South East (Cape Girardeau, MO)	25.7	22.8	20.9	18.5
South West (Kaiser, MO)	26.6	23.6	21.6	19.2
St Louis, MO	24.0	21.3	19.5	17.3
Kansas City, MO	22.6	20.0	18.4	16.3
Average/Unknown (Knob Noster)	23.8	21.1	19.3	17.1

HDD = Heating Degree Days

= Dependent on location:[512]

Climate Zone (City based upon)	HDD 60
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	3528
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[513] - If not available, use 71%[514]

Other factors as defined above

Conservative Deemed Approach

[512] The calculations made in this measure have been based on using Climate Normals data 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[513] 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.

[514] 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 and 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.

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[515]

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

SqFt = Building square footage

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AIRS-V01-170331

[515] 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.

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 types: 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.[516]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Residential Cooling

Residential Central Heat

Residential Heat Pump

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

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

(Minimum of R-5 for uninsulated assemblies[517])

A_{Attic} = Total area of insulated ceiling/attic (ft^2)

$FramingFactor_{Attic}$ = Adjustment to account for area of framing

= 7%[518]

CDD = Cooling Degree Days

= Dependent on location[519]:

Climate Zone (City based upon)	CDD 65
North East (Fort Madison, IA)	1200
North West (Lincoln, NE)	1174
South East (Cape Girardeau, MO)	1453
South West (Kaiser, MO)	1344
St Louis, MO	1646
Kansas City, MO	1360
Average/Unknown (Knob Noster)	1278

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [520]

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:[521]

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

[517] 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).
[518] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1
[519] Based on Climate Normals data with a base temp of 65°F.
[520] This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.
[521] 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.

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

= Dependent on location:[522]

Climate Zone (City based upon)	HDD 60
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	3528
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037

ηHeat = Efficiency of heating system

= Actual - If not available, refer to default table below:[523]

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%[524]

[522] The calculations made in this measure have been based on using Climate Normals data 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions

[523] 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.

[524] 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.

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%[525]

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[526]

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

= Dependent on location:[527]

Climate Zone (City based upon)	HDD 60
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	3528
Kansas City, MO	4059
Average/Unknown (Knob	4037

525 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.

526 Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

527 The calculations made in this measure have been based on using Climate Normals data 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

Climate Zone (City based upon)	HDD 60
Noster)	

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual.[528] If unknown assume 71%[529].

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: RS-SHL-AINS-V01-170331

528 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.

529 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 and 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 types: 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.[530]

DEEMED MEASURE COST

The actual duct insulation measure cost should be used.

LOADSHAPE

Residential Electric Heating and Cooling

Residential Electric Space Heat

Residential Cooling

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

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

$$\Delta kWhCooling = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLHcool * \Delta T_{AVG,cooling}}{(1{,}000 * SEER)}$$

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 (ft^2) = Area of the duct surface exposed to the unconditioned space that has been insulated

EFLHcool = Equivalent Full Load Cooling Hours

= Dependent on location[531]:

Climate Region (City based upon)	EFLHcool (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

$\Delta T_{AVG,cooling}$ = Average temperature difference (^{0}F) during cooling season between outdoor air temperature and assumed 60^{0}F duct supply air temperature[532]

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][533]	$\Delta T_{AVG,cooling}$ [°F]
North East (Fort Madison, IA)	76.2	16.2
North West (Lincoln, NE)	78.8	18.8
South East (Cape Girardeau, MO)	79.4	19.4
South West (Kaiser, MO)	81.3	21.3
St Louis, MO	80.8	20.8

[531] 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).

[532] Leaving coil air temperatures are typically about 55^{0}F. 60^{0}F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

[533] 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.

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][533]	$\Delta T_{AVG,cooling}$ [°F]
Kansas City, MO	79.0	19.0
Average/Unknown (Knob Noster)	80.7	20.7

1,000 = Converts Btu to kBtu

SEER = Efficiency in SEER of air conditioning equipment

= Actual - If not available, use[534]:

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

= Dependent on location[535]:

Climate Region (City based upon)	EFLHheat (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

[534] 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.

[535] 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 Climate Normals Heating Degree Day ratios (at 60F set point). NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

$\Delta T_{AVG,heating}$ = Average temperature difference (^{0}F) during heating season between outdoor air temperature and assumed 115^{0}F duct supply temperature[536]

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][537]	$\Delta T_{AVG,heating}$ [°F]
North East (Fort Madison, IA)	42.1	72.9
North West (Lincoln, NE)	39.0	76.0
South East (Cape Girardeau, MO)	45.7	69.3
South West (Kaiser, MO)	45.0	70.0
St Louis, MO	43.2	71.8
Kansas City, MO	40.3	74.7
Average/Unknown (Knob Noster)	43.4	71.6

3,412 = Converts Btu to kWh

COP = Efficiency in COP of heating equipment

= Actual - If not available, use[538]:

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

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

536 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.

537 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.

538 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.

= 3.14%[539]

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

= 0.0009474181[540]

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: RS-SHL-DUCT-V01-170331

539 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.

540 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf”

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 types: 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.[541]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Residential Cooling

Residential Central Heat

Residential Heat Pump

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.

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

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

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 [542]

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% [543]

24 = Converts hours to days

CDD = Cooling Degree Days

Climate Zone (City based upon)	Unconditioned Space CDD 75 [544]
North East (Fort Madison, IA)	96
North West (Lincoln, NE)	585
South East (Cape Girardeau, MO)	593
South West (Kaiser, MO)	563
St Louis, MO	814
Kansas City, MO	762
Average/Unknown (Knob Noster)	509

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [545]

1000 = Converts Btu to kBtu

542 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

543 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

544 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.

545 Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

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:[546]

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:

Climate Zone (City based upon)	Unconditioned Space
	HDD 50 [547]
North East (Fort Madison, IA)	2635
North West (Lincoln, NE)	2973
South East (Cape Girardeau, MO)	1747
South West (Kaiser, MO)	1886
St Louis, MO	1911
Kansas City, MO	2008
Average/Unknown (Knob Noster)	2259

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[548]

546 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.

547 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.

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

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*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%[549]

Other factors as defined above

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%[550]

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[551]

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

549 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.

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

551 Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

= Actual[552] - If not available, use 71%[553]

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: RS-SHL-FINS-V01-170331

[552] 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.

[553] 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 and 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 types: 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.[554]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Residential Cooling

Residential Central Heat

Residential Heat Pump

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

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

$$= \frac{\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

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[555]

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[556]

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space
	CDD 65 [557]	CDD 75 [558]
North East (Fort Madison, IA)	1200	585
North West (Lincoln, NE)	1174	593
South East (Cape Girardeau, MO)	1453	563
South West (Kaiser, MO)	1344	814
St Louis, MO	1646	762
Kansas City, MO	1360	509
Average/Unknown (Knob Noster)	1278	585

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

555 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

556 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

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

558 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.

= 0.75 [559]

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:[560]

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

[559] 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.

[560] 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 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) [561]

= 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

561 Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

H_{BWT} = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space
	HDD 60 [562]	HDD 50 [563]
North East (Fort Madison, IA)	4475	2,635
North West (Lincoln, NE)	4905	2,973
South East (Cape Girardeau, MO)	3368	1,747
South West (Kaiser, MO)	3561	1,886
St Louis, MO	3528	1,911
Kansas City, MO	4059	2,008
Average/Unknown (Knob Noster)	4037	2,259

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[564]

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

$ADJ_{Basement}$= Adjustment for basement wall insulation to account for prescriptiveengineering algorithms overclaiming savings.

= 88%[565]

[562] 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[563] 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.

[564] 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.

[565] 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.

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%[566]

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[567]

566 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.

567 Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

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[568] - If not available, use 71%[569]

100,000 = Converts Btu to Therms

Other factors as defined above

568 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.

569 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 and 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.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-BINS-V01-170331

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 types: 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[570]

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[571]. For clear glazing, cost can be assumed as $\$6.72/ft^2$ of window area (material cost) plus $30 per window for installation expenses[572]

LOADSHAPE

Residential Cooling

Residential Central Heat

Residential Heat Pump

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570 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.

571 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.

572 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[573]. 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.

North East (Fort Madison, IA)

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	50.1	14.5	50.9	13.3
	CLEAR INTERIOR	52.2	19.2	51.4	15.1
	LOW-E EXTERIOR	54.8	15.0	56.6	20.7
	LOW-E INTERIOR	61.1	22.0	59.3	19.0

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	18.0	8.8	17.5	8.0
	CLEAR INTERIOR	18.7	8.7	19.2	8.0
	LOW-E EXTERIOR	23.8	13.3	23.5	7.3
	LOW-E INTERIOR	22.7	11.7	23.1	11.2

North West (Lincoln, NE)

Heating:

573 Savings factors are based on simulation results, documented in “Storm Windows Savings.xlsx”

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	59.4	17.8	60.2	16.3
	CLEAR INTERIOR	61.9	23.0	61.1	18.4
	LOW-E EXTERIOR	65.6	19.1	67.6	24.4
	LOW-E INTERIOR	72.4	26.7	70.5	23.3

Cooling:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	21.9	10.0	21.4	9.1
	CLEAR INTERIOR	22.8	10.1	23.3	9.4
	LOW-E EXTERIOR	28.0	14.6	27.7	8.6
	LOW-E INTERIOR	27.2	13.3	27.5	12.7

South East (Cape Girardeau, MO)

Heating:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	40.4	10.8	41.2	9.9
	CLEAR INTERIOR	42.1	14.9	41.4	11.7
	LOW-E EXTERIOR	43.0	10.1	44.6	16.3
	LOW-E INTERIOR	48.7	16.6	47.1	14.2

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	18.8	9.1	18.3	8.3
	CLEAR INTERIOR	19.6	9.1	20.1	8.3
	LOW-E EXTERIOR	24.8	13.7	24.5	7.7
	LOW-E INTERIOR	23.8	12.2	24.1	11.6

South West (Kaiser, 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	39.2	10.9	40.0	9.9
	CLEAR INTERIOR	40.8	14.9	40.0	11.4
	LOW-E EXTERIOR	42.6	10.6	44.2	16.7
	LOW-E INTERIOR	48.1	17.0	46.4	14.3

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	20.6	9.9	20.1	8.9
	CLEAR INTERIOR	21.4	9.9	21.9	9.0
	LOW-E EXTERIOR	27.1	14.7	26.8	8.6
	LOW-E INTERIOR	26.1	13.3	26.4	12.6

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

Kansas City, 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	57.7	16.8	58.5	15.5
	CLEAR INTERIOR	60.3	22.0	59.5	17.8
	LOW-E EXTERIOR	63.0	17.6	64.8	23.1
	LOW-E INTERIOR	69.8	25.1	67.9	22.0

Cooling:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	25.4	11.0	24.9	10.1
	CLEAR INTERIOR	26.6	11.4	27.1	10.6
	LOW-E EXTERIOR	31.7	15.7	31.4	9.6
	LOW-E INTERIOR	31.1	14.6	31.4	14.0

Average/Unknown (Knob Noster)

Heating:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	49.2	13.7	50.0	12.7
	CLEAR INTERIOR	51.4	18.4	50.6	14.7
	LOW-E EXTERIOR	53.0	13.7	54.7	19.6
	LOW-E INTERIOR	59.2	20.7	57.5	18.0

Cooling:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	19.7	9.5	19.2	8.6
	CLEAR INTERIOR	20.5	9.5	20.9	8.6
	LOW-E EXTERIOR	25.9	14.2	25.6	8.1
	LOW-E INTERIOR	24.9	12.7	25.2	12.1

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[574]:

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

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[575]:

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

574 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.

575 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.

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[576]

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[577] - If not available, use 71%[578]

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: RS-SHL-STRM-V01-170331

576 Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

577 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.

578 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 and 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 types: 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.[579]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Residential Cooling

Residential Central Heat

Residential Heat Pump

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

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

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[580])

A_{Wall} = Net area of insulated wall (ft^2)

$FramingFactor_{Wall}$ = Adjustment to account for area of framing

= 25%[581]

CDD = Cooling Degree Days

= Dependent on location[582]:

Climate Zone (City based upon)	CDD 65
North East (Fort Madison, IA)	1200
North West (Lincoln, NE)	1174
South East (Cape Girardeau, MO)	1453
South West (Kaiser, MO)	1344
St Louis, MO	1646
Kansas City, MO	1360
Average/Unknown (Knob Noster)	1278

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [583]

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:[584]

Age of Equipment	ηCool Estimate
Before 2006	10
2006 - 2014	13
Central AC after 1/1/2015	13

580 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).

581 ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1.

582 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temperature of 65°F.

583 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.

584 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
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

= Dependent on location:[585]

Climate Zone (City based upon)	HDD 60
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	3528
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037

ηHeat = Efficiency of heating system

= Actual - If not available, refer to default table below:[586]

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

585 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

586 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.

algorithms consistently overclaiming savings

= 63%[587]

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%[588]

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[589]

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

= Dependent on location:[590]

Climate Zone (City based upon)	HDD 60
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau,	3368

587 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.

588 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.

589 Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

590 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. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

Climate Zone (City based upon)	HDD 60
MO)	
South West (Kaiser, MO)	3561
St Louis, MO	3528
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[591] - If not available, use 71%[592]

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: RS-SHL-WINS-V01-170331

591 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.

592 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 and 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.

3.7.8 Door

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.7.9 Window Film

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.7.10 Windows

This measure was not characterized for Version 1 of the Missouri Statewide TRM.

3.8 Miscellaneous End Use

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[593]). 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[594]	150	.07

DEFINITION OF EFFICIENT CASE

The efficient case is a customer who receives a Home Energy Report.

DEFINITION OF BASELINE CASE

The baseline case is a customer who does not receive a Home Energy Report.

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

Residential Electric Heating and Cooling

[593] 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.

[594] 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 MO 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).

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RES-MISC-HER-V01-170331