Illinois Statewide Technical Reference Manual for Energy Efficiency

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Volume 3: Residential Measures

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Volume 3: Residential Measures

5.1 Appliances End Use

5.1.1 ENERGY STAR Air Purifier/Cleaner

DESCRIPTION

An air purifier (cleaner) meeting the efficiency specifications of ENERGY STAR is purchased and installed in place of a model meeting the current federal standard.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust[1] 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[2].

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 9 years[3].

DEEMED MEASURE COST

The incremental cost for this measure is $70.[4]

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 100 % (the unit is assumed to be always on).

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

kWh_{BASE} = Baseline kWh consumption per year[5]

= see table below

kWh_{ESTAR} = ENERGY STAR kWh consumption per year[6]

= 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

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5844 hours[7]

CF = Summer Peak Coincidence Factor for measure

= 66.7%[8]

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

[5] ENERGY STAR Qualified Room Air Cleaner Calculator.
[6] Ibid.
[7] Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator assumption of 16 hours per day (16 * 365.25 = 5844).
[8] Assumes that the purifier usage is evenly spread throughout the year, therefore coincident peak is calculated as 5844/8766 = 66.7%.

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.[9]

MEASURE CODE: RS-APL-ESAP-V02-160601

REVIEW DEADLINE: 1/1/2023

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

5.1.2 ENERGY STAR and ENERGY STAR Most Efficient Clothes Washers

Description

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

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

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

Definition of Efficient Equipment

Clothes washer must meet the ENERGY STAR or ENERGY STAR Most Efficient minimum qualifications, as required by the program.

Definition of Baseline Equipment

The baseline condition is a standard sized clothes washer meeting the minimum federal baseline as of March 2015[10].

Efficiency Level	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft
Federal Standard	1.29 IMEF, 8.4 IWF	1.84 IMEF, 4.7 IWF
ENERGY STAR	2.06 IMEF, 4.3 IWF	2.38 IMEF, 3.7 IWF
ENERGY STAR Most Efficient	2.76 IMEF, 3.5 IWF	2.74 IMEF, 3.2IWF

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 14 years[11].

Deemed Measure Cost

The incremental cost for an ENERGY STAR unit is assumed to be $65 and for an ENERGY STAR Most Efficient unit it is $210[12].

Deemed O&M Cost Adjustments

N/A

[10] See http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.
[11] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.html
[12] Cost estimates are based on Navigant analysis for the Department of Energy (see CW Analysis_09092014.xls). This analysis looked at incremental cost and shipment data from manufacturers and the Association of Home Appliance Manufacturers and attempts to find the costs associated only with the efficiency improvements. The ENERGY STAR level in this analysis was made the baseline (as it is now equivalent), the CEE Tier 3 level was made ENERGY STAR and ENERGY STAR Most efficient was extrapolated based on equal rates. Note these assumptions should be reviewed as qualifying product becomes available.

LOADSHAPE

Loadshape R01 - Residential Clothes Washer

COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%[13].

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

1. Calculate clothes washer savings based on Modified Energy Factor (MEF).

   The Modified Energy Factor (MEF) includes unit operation, water heating and drying energy use: *"MEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, and the energy required for removal of the remaining moisture in the wash load, D"* [14].

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

IMEFsavings[15] = Capacity * (1/IMEFbase - 1/IMEFeff) * Ncycles

Where

Capacity = Clothes Washer capacity (cubic feet)

= Actual. If capacity is unknown assume 3.45 cubic feet [16]

IMEFbase = Integrated Modified Energy Factor of baseline unit

= 1.66[17]

IMEFeff = Integrated Modified Energy Factor of efficient unit

= Actual. If unknown assume average values provided below.

Ncycles = Number of Cycles per year

= 295[18]

[13] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.
[14] Definition provided on the Energy star website.
[15] IMEFsavings represents total kWh only when water heating and drying are 100% electric.
[16] Based on the average clothes washer volume of all units that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 08/28/2014. 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.
[17] 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.
[18] Weighted average of 295 clothes washer cycles per year (based on 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, state of IL: http://www.eia.gov/consumption/residential/data/2009/
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.

IMEFsavings is provided below based on deemed values[19]:

Efficiency Level	IMEF	IMEFSavings (kWh)
Federal Standard	1.66	0.0
ENERGY STAR	2.26	163
ENERGY STAR Most Efficient	2.74	242

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

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

Where:

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

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

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

	Percentage of Total Energy Consumption[20]		
	%CW	%DHW	%Dryer
Baseline	7.6%	31.2%	61.2%
ENERGY STAR	8.1%	23.4%	68.5%
ENERGY STAR Most Efficient	13.6%	10%	76.3%

%Electric_DHW = Percentage of DHW savings assumed to be electric

DHW fuel	%Electric_DHW
Electric	100%
Natural Gas	0%
Unknown	16%[21]

%Electric_Dryer = Percentage of dryer savings assumed to be electric

Dryer fuel	%Electric_Dryer
Electric	100%

[19] IMEF values are the weighted average of the new ENERGY STAR specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and ENERGY STAR Most Efficient product in the CEC database. See “CW Analysis_01142016.xls” for the calculation.

[20] The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units based on data from DOE Life-Cycle Cost and Payback Period Excel-based analytical tool. See “CW Analysis_01142016.xls” for the calculation.

[21] 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

Dryer fuel	%Electric_Dryer
Natural Gas	0%
Unknown	36%[22]

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

	ΔkWH								
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer	Electric DHW Unknown Dryer	Gas DHW Unknown Dryer	Unknown DHW Electric Dryer	Unknown DHW Gas Dryer	Unknown DHW Unknown Dryer
ENERGY STAR	162.7	77.0	96.0	10.2	120.0	34.3	90.7	24.0	48.0
ENERGY STAR Most Efficient	242.1	88.2	149.9	-4.0	183.1	29.2	112.8	20.6	53.8

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Assumed Run hours of Clothes Washer

= 295 hours[23]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[24]

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

	ΔkW								
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer	Electric DHW Unknown Dryer	Gas DHW Unknown Dryer	Unknown DHW Electric Dryer	Unknown DHW Gas Dryer	Unknown DHW Unknown Dryer
ENERGY STAR	0.0210	0.0099	0.0124	0.0013	0.0155	0.0044	0.0117	0.0031	0.0062
ENERGY STAR Most Efficient	0.0312	0.0114	0.0193	-0.0005	0.0236	0.0038	0.0145	0.0027	0.0069

NATURAL GAS SAVINGS

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

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

[22] Default assumption for unknown is based on percentage of homes with electric dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of 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.
[23] Based on a weighted average of 295 clothes washer cycles per year assuming an average load runs for one hour (2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/)
[24] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

(%Dryereff * %Gas_Dryer)))] * Therm_convert

Where:

Therm_convert = Convertion factor from kWh to Therm

= 0.03413

R_eff = Recovery efficiency factor

= 1.26[25]

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

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[26]

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

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%
Unknown	58%[27]

Other factors as defined above

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

	ΔTherms								
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer	Electric DHW Unknown Dryer	Gas DHW Unknown Dryer	Unknown DHW Electric Dryer	Unknown DHW Gas Dryer	Unknown DHW Unknown Dryer
ENERGY STAR	0.00	3.7	2.3	6.0	1.3	5.0	3.1	5.4	4.4
ENERGY STAR Most Efficient	0.00	6.6	3.1	9.8	1.8	8.4	5.6	8.7	7.4

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Where

IWFbase = Integrated Water Factor of baseline clothes washer

= 5.92[28]

[25] 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.

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

[27] Ibid.

[28] 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.

IWFeff = Water Factor of efficient clothes washer

= Actual. If unknown assume average values provided below.

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

Efficiency Level	IWF[29]	ΔWater (gallons per year)
Federal Standard	5.92	0.0
ENERGY STAR	3.93	2024
ENERGY STAR Most Efficient	3.21	2760

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESCL-V04-160601

REVIEW DEADLINE: 1/1/2021

[29] 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 “CW Analysis_01142016.xls” for the calculation.

5.1.3 ENERGY STAR Dehumidifier

Description

A dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR Version 3.0 (effective 10/1/2012)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	≥1.85
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[30].

Deemed Measure Cost

The assumed incremental capital cost for this measure is $60[31].

Loadshape

Loadshape R12 - Residential - Dehumidifier

[30] EPA Research, 2012; ENERGY STAR Dehumidifier Calculator
[31] Based on extrapolating available data from the Department of Energy's Life Cycle Cost analysis spreadsheet and weighting based on volume of units available:
See 'DOE life cycle cost_dehumidifier.xls' for calculation.

Coincidence Factor

The coincidence factor is assumed to be 37% [32].

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

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

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

0.473 = Constant to convert Pints to Liters

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

Hours = Run hours per year

= 1632 [33]

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	1.85	477	348	129
> 25 to ≤35	30	1.35	1.85	715	522	193
> 35 to ≤45	40	1.5	1.85	858	695	162
> 45 to ≤ 54	50	1.6	1.85	1005	869	136
> 54 to ≤ 75	65	1.7	1.85	1230	1130	100
> 75 to ≤ 185	130	2.5	2.8	1673	1493	179
Average[34]						140

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/Hours * CF

[32] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

[33] ENERGY STAR Dehumidifier Calculator; 24 hour operation over 68 days of the year.

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

Where:

Hours = Annual operating hours

= 1632 hours [35]

CF = Summer Peak Coincidence Factor for measure

= 0.37 [36]

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

Capacity (pints/day) Range	Annual Summer peak kW Savings
≤25	0.029
> 25 to ≤35	0.044
> 35 to ≤45	0.037
> 45 to ≤ 54	0.031
> 54 to ≤ 75	0.023
> 75 to ≤ 185	0.041
Average	0.032

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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REVIEW DEADLINE: 1/1/2019

[35] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator

[36] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

5.1.4 ENERGY STAR Dishwasher

Description

A dishwasher meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard. This measure is only for standard dishwashers, not compact dishwashers. A compact dishwasher is a unit that holds less than eight place settings with six serving pieces.

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

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

Definition of Efficient Equipment

The efficient equipment is defined as a dishwasher meeting the efficiency specifications of ENERGY STAR. The Energy Star standard is presented in the table below:

Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle
Standard (≥ 8 place settings + six serving pieces)	270	3.5
Standard with Connected Functionality[37]	283	
Compact (< 8 place settings + six serving pieces)	203	3.1

Definition of Baseline Equipment

The Baseline reflects the minimum federal efficiency standards for dishwashers effective May 30, 2013, as presented in the table below[38].

Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle
Standard	307	5.0
Compact	222	3.5

Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 13 years[39].

Deemed Measure Cost

The incremental cost for this measure is $50[40].

[37] The new ENERGY STAR specification "establishes optional connected criteria for dishwashers. ENERGY STAR certified dishwashers with connected functionality offer favorable attributes for demand response programs to consider, since their peak energy consumption is relatively high, driven by water heating. ENERGY STAR certified dishwashers with connected functionality will offer consumers new convenience and energy-saving features, such as alerts for cycle completion and/or recommended maintenance, as well as feedback on the energy use of the product". See 'ENERGY STAR Residential Dishwasher Final Version 6.0 Cover Memo.pdf'. Calculated as per Version 6.0 specification; "ENERGY STAR Residential Dishwasher Version 6.0 Final Program Requirements.pdf". Note that the potential for demand response and additional peak savings from units with Connected Functionality have not been explored. This could be a potential addition in a future version.

[38] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67

[39] Koomey, Jonathan et al. (Lawrence Berkeley National Lab), Projected Regional Impacts of Appliance Efficiency Standards for the U.S. Residential Sector, February 1998.

[40] Estimate based on review of Energy Star stakeholder documents

Loadshape

Loadshape R02 - Residential Dish Washer

Coincidence Factor

The coincidence factor is assumed to be 2.6%[41].

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh^{42} = ((kWh_{Base} - kWh_{ESTAR}) * (\%kWh\_op + (\%kWh\_heat * \%Electric\_DHW)))$$

Where:

kWh_{BASE} = Baseline kWh consumption per year

Dishwasher Type	Maximum kWh/year
Standard	307
Compact	222

kWh_{ESTAR} = ENERGY STAR kWh annual consumption

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

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

= 1 - 56%[43]

= 44%

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

= 56%[44]

%Electric_DHW = Percentage of DHW savings assumed to be electric

DHW fuel	%Electric_DHW
Electric	100%
Natural Gas	0%

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

[42] The Federal Standard and ENERGY STAR annual consumption values include electric consumption for both the operation of the machine and for heating the water that is used by the machine.

[43] ENERGY STAR Dishwasher Calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerDishwasher.xls)

[44] Ibid.

DHW fuel	%Electric_DHW
Unknown	16%[45]

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS[46]

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

Where:

Hours = Annual operating hours[47]

= 252 hours

CF = Summer Peak Coincidence Factor

= 2.6% [48]

Dishwasher Type	ΔkW		
	With Electric DHW	With Gas DHW	With Unknown DHW
ENERGY STAR Standard	0.0038	0.0017	0.0020
ENERGY STAR Standard with Connected Functionality	0.0025	0.0011	0.0013
ENERGY STAR Compact	0.0020	0.0009	0.0010

NATURAL GAS SAVINGS

$$\Delta Therm = (kWh_{Base} - kWh_{ESTAR}) * \%kWh\_heat * \%Natural Gas\_DHW * R\_eff * 0.03413$$

Where

%kWh_heat = % of dishwasher energy used for water heating

= 56%

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

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%

45 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.

46 Note that the potential for demand response and additional peak savings from units with Connected Functionality have not been explored. This could be a potential addition in a future version.

47 Assuming one and a half hours per cycle and 168 cycles per year therefore 252 operating hours per year; 168 cycles per year is based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

48 End use data from Ameren representing the average DW load during peak hours/peak load.

DHW fuel	%Natural Gas_DHW
Unknown	84%[49]

R_eff = Recovery efficiency factor

= 1.26[50]

0.03413 = factor to convert from kWh to Therm

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water = Water_{Base} - Water_{EFF}$$

Where

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

Dishwasher Type	$Water_{Base}$ (gallons) [51]
Standard	840
Compact	588

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

Dishwasher Type	$Water_{EFF}$ (gallons) [52]
Standard	588
Compact	521

Dishwasher Type	ΔWater (gallons) [53]
Standard	252
Compact	67

[49] 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.

[50] 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.

[51] Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

[52] Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

[53] Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESDI-V03-160601

REVIEW DEADLINE: 6/1/2018

5.1.5 ENERGY STAR Freezer

Description

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

Product Category	Volume (cubic feet)	Assumptions up to September 2014		Assumptions after September 2014	
		Federal Baseline Maximum Energy Usage in kWh/year[54]	ENERGY STAR Maximum Energy Usage in kWh/year[55]	Federal Baseline Maximum Energy Usage in kWh/year[56]	ENERGY STAR Maximum Energy Usage in kWh/year[57]
Upright Freezers with Manual Defrost	7.75 or greater	7.55*AV+258.3	6.795*AV+232.47	5.57*AV + 193.7	5.01*AV + 174.3
Upright Freezers with Automatic Defrost	7.75 or greater	12.43*AV+326.1	11.187*AV+293.49	8.62*AV + 228.3	7.76*AV + 205.5
Chest Freezers and all other Freezers except Compact Freezers	7.75 or greater	9.88*AV+143.7	8.892*AV+129.33	7.29*AV + 107.8	6.56*AV + 97.0
Compact Upright Freezers with Manual Defrost	< 7.75 and 36 inches or less in height	9.78*AV+250.8	7.824*AV+200.64	8.65*AV + 225.7	7.79*AV + 203.1
Compact Upright Freezers with Automatic Defrost	< 7.75 and 36 inches or less in height	11.40*AV+391	9.12*AV+312.8	10.17*AV + 351.9	9.15*AV + 316.7
Compact Chest Freezers	<7.75 and 36 inches or less in height	10.45*AV+152	8.36*AV+121.6	9.25*AV + 136.8	8.33*AV + 123.1

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

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

Definition of Efficient Equipment

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

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

[54] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
[55] http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls?c827-f746
[56] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
[57] http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Specification.pdf

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 11 years[58].

Deemed Measure Cost

The incremental cost for this measure is $35[59].

Loadshape

Loadshape R04 - Residential Freezer

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 95%[60].

Algorithm

Calculation of Savings

Electric Energy Savings:

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

Where:

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

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

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

$$\Delta kWh = (5.57*(7.75* 1.73)+193.7) – (5.01*(7.75* 1.73)+174.3)$$

$$= 268.4 – 241.5$$

$$= 26.9 \text{ kWh}$$

If volume is unknown, use the following default values:

[58] Energy Star Freezer Calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Freezer_Sav_Calc.xls?570a-f000

[59] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009.

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

Product Category	Volume Used[61]	Assumptions up to September 2014			Assumptions after September 2014		
		kWh_{BASE}	kWh_{ESTAR}	kWh Savings	kWh_{BASE}	kWh_{ESTAR}	kWh Savings
Upright Freezers with Manual Defrost	27.9	469.1	422.2	46.9	349.2	314.2	35.0
Upright Freezers with Automatic Defrost	27.9	673.2	605.9	67.3	469.0	422.2	46.8
Chest Freezers and all other Freezers except Compact Freezers	27.9	419.6	377.6	42.0	311.4	280.2	31.2
Compact Upright Freezers with Manual Defrost	10.4	352.3	281.9	70.5	467.2	420.6	46.6
Compact Upright Freezers with Automatic Defrost	10.4	509.3	407.5	101.9	635.9	572.2	63.7
Compact Chest Freezers	10.4	260.5	208.4	52.1	395.1	355.7	39.4

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/ Hours * CF

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Full Load hours per year

= 5890[62]

CF = Summer Peak Coincident Factor

= 0.95 [63]

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

ΔkW = 26.9/5890 * 0.95

= 0.0043 kW

If volume is unknown, use the following default values:

Product Category	Assumptions up to September 2014	Assumptions after September 2014
	kW Savings	kW Savings
Upright Freezers with Manual Defrost	0.0076	0.0057
Upright Freezers with Automatic Defrost	0.0109	0.0076
Chest Freezers and all other Freezers except Compact Freezers	0.0068	0.0050
Compact Upright Freezers with Manual Defrost	0.0114	0.0075

[61] Volume is based on ENERGY STAR Calculator assumption of 16.14 ft^3 average volume, converted to Adjusted volume by multiplying by 1.73.
[62] Calculated from eShapes Residential Freezer load data as provided by Ameren by dividing total annual load by the maximum kW in any one hour.
[63] Based on eShapes Residential Freezer load data as provided by Ameren.

Product Category	Assumptions up to September 2014	Assumptions after September 2014
	kW Savings	kW Savings
Compact Upright Freezers with Automatic Defrost	0.0164	0.0103
Compact Chest Freezers	0.0084	0.0064

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESFR-V02-140601

REVIEW DEADLINE: 1/1/2021

5.1.6 ENERGY STAR and CEE Tier 2 Refrigerator

DESCRIPTION

This measure relates to:

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

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

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

Product Category	Existing Unit	Assumptions up to September 2014		Assumptions after September 2014	
	Based on Refrigerator Recycling algorithm	Federal Baseline Maximum Energy Usage in kWh/year[64]	ENERGY STAR Maximum Energy Usage in kWh/year[65]	Federal Baseline Maximum Energy Usage in kWh/year[66]	ENERGY STAR Maximum Energy Usage in kWh/year[67]
1. Refrigerators and Refrigerator-freezers with manual defrost	Use Algorithm in 5.1.8 Refrigerator and Freezer Recycling measure to estimate existing unit consumption	8.82*AV+248.4	7.056*AV+198.72	6.79AV + 193.6	6.11 * AV + 174.2
2. Refrigerator-Freezer--partial automatic defrost		8.82*AV+248.4	7.056*AV+198.72	7.99AV + 225.0	7.19 * AV + 202.5
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost		9.80*AV+276	7.84*AV+220.8	8.07AV + 233.7	7.26 * AV + 210.3
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service		4.91*AV+507.5	3.928*AV+406	8.51AV + 297.8	7.66 * AV + 268.0
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer		4.60*AV+459	3.68*AV+367.2	8.85AV + 317.0	7.97 * AV + 285.3

[64] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
[65] http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls?c827-f746
[66] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
[67]http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Specification.pdf

Product Category	Existing Unit	Assumptions up to September 2014		Assumptions after September 2014	
	Based on Refrigerator Recycling algorithm	Federal Baseline Maximum Energy Usage in kWh/year[64]	ENERGY STAR Maximum Energy Usage in kWh/year[65]	Federal Baseline Maximum Energy Usage in kWh/year[66]	ENERGY STAR Maximum Energy Usage in kWh/year[67]
without through-the-door ice service					
5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service		N/A	N/A	9.25AV + 475.4	8.33 * AV + 436.3
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service		10.20*AV+356	8.16*AV+284.8	8.40AV + 385.4	7.56 * AV + 355.3
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service		10.10*AV+406	8.08*AV+324.8	8.54AV + 432.8	7.69 * AV + 397.9

Note CEE Tier 2 standard criteria is 25% less consumption than a new baseline unit. It is assumed that after September 2014 when the Federal Standard and ENERGY STAR specifications change, the CEE Tier 2 will remain set at 25% less that the new baseline assumption.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a refrigerator meeting the efficiency specifications of ENERGY STAR or CEE Tier 2 (defined as requiring >= 20% or >= 25% less energy consumption than an equivalent unit meeting federal standard requirements respectively). The ENERGY STAR standard varies according to the size and configuration of the unit, as shown in table above.

DEFINITION OF BASELINE EQUIPMENT

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

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

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 12 years.[68]

Remaining life of existing equipment is assumed to be 4 years[69]

Deemed Measure Cost

Time of Sale: The incremental cost for this measure is assumed to be $40[70] for an ENERGY STAR unit and $140[71] for a CEE Tier 2 unit.

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable assume $451 for ENERGY STAR unit and $551 for CEE Tier 2 unit[72].

The avoided replacement cost (after 4 years) of a baseline replacement refrigerator is $413[73]. This cost should be discounted to present value using the nominal societal discount rate.

Loadshape

Loadshape R05 - Residential Refrigerator

Coincidence Factor

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

Algorithm

Calculation of Savings

Electric Energy Savings:

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

Early Replacement:

ΔkWh for remaining life of existing unit (1st 4 years) $= UEC_{EXIST} – UEC_{EE}$

ΔkWh for remaining measure life (next 8 years) $= UEC_{BASE} – UEC_{EE}$

Where:

UEC_{EXIST} = Annual Unit Energy Consumption of existing unit as calculated in algorithm from 5.1.8 Refrigerator and Freezer Recycling measure.

UEC_{BASE} = Annual Unit Energy Consumption of baseline unit as calculated in algorithm provided in

68 From ENERGY STAR calculator: http://www.energystar.gov/buildings/sites/default/uploads/files/appliance_calculator.xlsx?7224-046c=&7224-__046ceiling_fan_calculator_xlsx=&f7d8-39dd&f7d8-39dd

69 Standard assumption of one third of effective useful life.

70 From ENERGY STAR calculator linked above.

71 Based on weighted average of units participating in Efficiency Vermont program and retail cost data provided in Department of Energy, "TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers", October 2005; http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf

72 ENERGY STAR full cost is based upon IL PHA Efficient Living Program data on sample size of 910 replaced units finding average cost of $430 plus an average recycling/removal cost of $21. The CEE Tier 2 estimate uses the delta from the Time of Sale estimate.

73 Calculated using incremental cost from Time of Sale measure and applying inflation rate of 1.91%.

table above.

UEC_{EE} = Annual Unit Energy Consumption of ENERGY STAR unit as calculated in algorithm provided in table above.

For CEE Tier 2, unit consumption is calculated as 25% lower than baseline.

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8[74]:

Assumptions prior to standard changes on September 1st, 2014:

Product Category	Existing Unit UEC_{EXIST} [75]	New Baseline UEC_{BASE}	New Efficient UEC_{EE}		Early Replacement (1st 4 years) ΔkWh		Time of Sale and Early Replacement (last 8 years) ΔkWh	
			ENERGY STAR	CEE T2	ENERGY STAR	CEE T2	ENERGY STAR	CEE T2
1. Refrigerators and Refrigerator-freezers with manual defrost	1027.7	475.7	380.5	356.8	647.2	671.0	95.1	118.9
2. Refrigerator-Freezer--partial automatic defrost	1027.7	475.7	380.5	356.8	647.2	671.0	95.1	118.9
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	814.5	528.5	422.8	396.4	391.7	418.1	105.7	132.1
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	1241.0	634.0	507.2	475.5	733.7	765.4	126.8	158.5
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	814.5	577.5	462.0	433.2	352.5	381.4	115.5	144.4
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	814.5	618.8	495.1	464.1	319.5	350.4	123.8	154.7
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	1241.0	666.3	533.0	499.7	707.9	741.3	133.3	166.6

Assumptions after standard changes on September 1st, 2014:

[74] Volume is based on the ENERGY STAR calculator average assumption of 14.75 ft^3 fresh volume and 6.76 ft^3 freezer volume.
[75] Estimates of existing unit consumption are based on using the 5.1.8 Refrigerator and Freezer Recycling algorithm and the inputs described here: Age = 10 years, Pre-1990 = 0, Size = 21.5 ft3 (from ENERGY STAR calc and consistent with AV of 25.8), Single Door = 0, Side by side = 1 for classifications stating side by side, 0 for classifications stating top/bottom, and 0.5 for classifications that do not distinguish, Primary appliances = 1, unconditioned = 0, Part use factor = 0.

Product Category	Existing Unit UEC_{EXIST} [76]	New Baseline UEC_{BASE}	New Efficient UEC_{EE}		Early Replacement (1st 4 years) ΔkWh		Time of Sale and Early Replacement (last 8 years) ΔkWh	
			ENERGY STAR	CEE T2	ENERGY STAR	CEE T2	ENERGY STAR	CEE T2
1. Refrigerators and Refrigerator-freezers with manual defrost	1027.7	368.6	331.6	276.4	696.1	751.3	36.9	92.1
2. Refrigerator-Freezer--partial automatic defrost	1027.7	430.9	387.8	323.2	640.0	704.6	43.1	107.7
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	814.5	441.7	397.4	331.2	417.2	483.3	44.3	110.4
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	1241.0	517.1	465.4	387.8	775.6	853.1	51.7	129.3
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	814.5	545.1	490.7	408.8	323.9	405.8	54.4	136.3
5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	814.5	713.8	651.0	535.3	163.6	279.2	62.8	178.4
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	814.5	601.9	550.1	451.4	264.4	363.2	51.7	150.5
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	1241.0	652.9	596.1	489.6	644.9	751.3	56.8	163.2

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh/8766) * TAF * LSAF

Where:

TAF = Temperature Adjustment Factor

[76] Estimates of existing unit consumption are based on using the 5.1.8 Refrigerator and Freezer Recycling algorithm and the inputs described here: Age = 10 years, Pre-1990 = 0, Size = 21.5 ft3 (from ENERGY STAR calc and consistent with AV of 25.8), Single Door = 0, Side by side = 1 for classifications stating side by side, 0 for classifications stating top/bottom, and 0.5 for classifications that do not distinguish, Primary appliances = 1, unconditioned = 0, Part use factor = 0.

= 1.25[77]

LSAF = Load Shape Adjustment Factor

= 1.057 [78]

If volume is unknown, use the following defaults:

Product Category	Assumptions prior to September 2014 standard change ΔkW				Assumptions after September 2014 standard change ΔkW			
	Early Replacement (1st 4 years)		Time of Sale and Early Replacement (last 8 years)		Early Replacement (1st 4 years)		Time of Sale and Early Replacement (last 8 years)	
	ENERGY STAR	CEE T2	ENERGY STAR	CEE T2	ENERGY STAR	CEE T2	ENERGY STAR	CEE T2
1. Refrigerators and Refrigerator-freezers with manual defrost	0.098	0.101	0.014	0.018	0.105	0.113	0.006	0.014
2. Refrigerator-Freezer--partial automatic defrost	0.098	0.101	0.014	0.018	0.096	0.106	0.006	0.016
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	0.059	0.063	0.016	0.020	0.063	0.073	0.007	0.017
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	0.111	0.115	0.019	0.024	0.117	0.129	0.008	0.019
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	0.053	0.057	0.017	0.022	0.049	0.061	0.008	0.021
5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	n/a	n/a	n/a	n/a	0.025	0.042	0.009	0.027
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	0.048	0.053	0.019	0.023	0.040	0.055	0.008	0.023
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	0.107	0.112	0.020	0.025	0.097	0.113	0.009	0.025

NATURAL GAS SAVINGS

N/A

[77] Average temperature adjustment factor (to account for temperature conditions during peak period as compared to year as a whole) based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47). It assumes 90 °F average outside temperature during peak period, 71°F average temperature in kitchens and 65°F average temperature in basement, and uses assumption that 66% of homes in Illinois have central cooling (CAC saturation: "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey; http://www.eia.gov/consumption/residential/data/2009/xls/HC7.9%20Air%20Conditioning%20in%20Midwest%20Region.xls)

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESRE-V05-180101

REVIEW DEADLINE: 1/1/2021

5.1.7 ENERGY STAR Room Air Conditioner

Description

This measure relates to:

a) Time of Sale the purchase and installation of a room air conditioning unit that meets ENERGY STAR version 4.0 which is effective October 26th 2015), in place of a baseline unit. The baseline is based on the Federal Standard effective June 1st, 2014.

Product Type and Class (Btu/hr)		Federal Standard with louvered sides (CEER) [79]	Federal Standard without louvered sides (CEER)	ENERGY STAR v4.0 with louvered sides (CEER) [80]	ENERGY STAR v4.0 without louvered sides (CEER)
Without Reverse Cycle	< 8,000	11.0	10.0	11.5	10.5
	8,000 to 10,999	10.9	9.6	11.4	10.1
	11,000 to 13,999	10.9	9.5	11.4	10.0
	14,000 to 19,999	10.7	9.3	11.2	9.7
	20,000 to 24,999	9.4	9.4	9.8	9.8
	>=25,000	9.0	9.4	9.4	9.8
With Reverse Cycle	<14,000	9.8	9.3	10.3	9.7
	14,000 to 19,999	9.8	8.7	10.3	9.1
	>=20,000	9.3	8.7	9.7	9.1
Casement only		9.5		10.0	
Casement-Slider		10.4		10.8	

Side louvers extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models.

Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.

Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.

Reverse cycle refers to the heating function found in certain room air conditioner models.

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

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

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

Definition of Efficient Equipment

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

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[79] See DOE's Appliance and Equipment Standards for Room AC; https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

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

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

DEFINITION OF BASELINE EQUIPMENT

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

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

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

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

DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $40 for a ENERGY STAR unit[85].

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

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

LOADSHAPE

Loadshape R08 - Residential Cooling

COINCIDENCE FACTOR

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Early Replacment:

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

[82] See DOE's Appliance and Equipment Standards for Room AC; https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41
[83] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf
[84] Standard assumption of one third of effective useful life.
[85] Incremental cost based on field study conducted by Efficiency Vermont.
[86] Based on IL PHA Efficient Living Program Data for 810 replaced units showing $416 per unit plus $32 average recycling/removal cost.
[87] Estimate based upon Time of Sale incremental costs and applying inflation rate of 1.91%.
[88] Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

1/CEERee))/1000

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

Where:

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

= dependent on location[89]:

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

Btu/H = Size of rebated unit

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

EERexist =Efficiency of existing unit

= Actual. If unknown assume 7.7[92]

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

CEERbase = Combined Energy Efficiency Ratio of baseline unit

= As provided in tables above

CEERee = Combined Energy Efficiency Ratio of ENERGY STAR unit

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

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

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

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

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

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

Time of Sale:

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

$\Delta kWH_{CEE\ TIER\ 1}$ = (248 * 8500 * (1/10.9 – 1/11.4)) / 1000

= 8.5 kWh

Early Replacement:

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

ΔkWh for remaining life of existing unit (1st 4 years) = (319 * 9000 * (1/(7.7/1.01) - 1/11.4))/1000

= 124.7 kWh

ΔkWh for remaining measure life (next 8 years) = (319 * 9000 * (1/10.9 - 1/11.4))/1000

= 11.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

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

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[94]

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

Other variable as defined above

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

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

Time of Sale:

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

$\Delta kW_{CEE\ TIER\ 1}$ = (8500 * (1/(10.9 * 1.01) – 1/(11.4*1.01))) / 1000 * 0.3

= 0.010 kW

Early Replacement:

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

ΔkW for remaining life of existing unit (1st 4 years) = (9000 * (1/7.7 - 1/(11.4 * 1.01)))/1000 * 0.3

= 0.12 kW

ΔkW for remaining measure life (next 8 years) = (9000 * (1/(10.9 * 1.01) - 1/(11.4 * 1.01)))/1000 * 0.3

= 0.011 kW

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESRA-V06-180101

REVIEW DEADLINE: 1/1/2021

5.1.8 Refrigerator and Freezer Recycling

DESCRIPTION

This measure describes savings from the retirement and recycling of inefficient but operational refrigerators and freezers. Savings are provided based on a 2013 workpaper provided by Cadmus that used data from a 2012 ComEd metering study and metering data from a Michigan study, to develop a regression equation that uses key inputs describing the retired unit. The savings are equivalent to the Unit Energy Consumption of the retired unit and should be claimed for the assumed remaining useful life of that unit. A part use factor is applied to account for those secondary units that are not in use throughout the entire year. The reader should note that the regression algorithm is designed to provide an accurate portrayal of savings for the population as a whole and includes those parameters that have a significant effect on the consumption. The precision of savings for individual units will vary.

The Net to Gross factor applied to these units should incorporate adjustments that account for:

- Those participants who would have removed the unit from the grid anyway (e.g. customers replacing their refrigerator via a big box store and using the pick-up option, customers taking their unit to the landfill or recycling station);
- Those participants who decided, based on the incentive provided by the Appliance Recycling program alone, to replace their existing inefficient unit with a new unit. This segment of participants is expected to be very small and documentation of their intentions will be gathered via telephone surveys (i.e., primary data sources). For such customers, the consumption of the new unit should be subtracted from the retired unit consumption and savings claimed for the remaining life of the existing unit. Note that participants who were already planning to replace their unit, and the incentive just ensured that the retired unit was recycled and not placed on the secondary market, should not be included in this adjustment.

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 [96].

DEEMED MEASURE COST

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

---

[96] KEMA "Residential refrigerator recycling ninth year retention study", 2004

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

LOADSHAPE

Loadshape R05 - Residential Refrigerator

COINCIDENCE FACTOR

The coincidence factor is assumed to be 0.00012.

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS[98]

Refrigerators:

Energy savings for refrigerators are based upon a linear regression model using the following coefficients[99]:

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

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

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

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

(= 1 if Primary, else 0)

Interaction: Located in Unconditioned Space x CDD/365.25

[98] Based on the specified regression, a small number of units may have negative energy and demand consumption. These are a function of the unit size and age, and should comprise a very small fraction of the population. While on an individual basis this result is counterintuitive it is important that these negative results remain such that as a population the average savings is appropriate.

[99] Energy savings are based on an average 30-year TMY temperature of 51.1 degrees. Coefficients provided in July 30, 2014 memo from Cadmus: “Appliance Recycling Update no single door July 30 2014”.

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

CDD = Cooling Degree Days

= Dependent on location[100]:

Climate Zone (City based upon)	CDD 65	CDD/365.25
1 (Rockford)	820	2.25
2 (Chicago)	842	2.31
3 (Springfield)	1,108	3.03
4 (Belleville)	1,570	4.30
5 (Marion)	1,370	3.75

Interaction: Located in Unconditioned Space x HDD/365.25

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

HDD = Heating Degree Days

= Dependent on location:[101]

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

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used[102]. For illustration purposes, this example uses 0.93.[103]

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

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

= 969 * 0.93

= 900.9 kWh

Freezers:

Energy savings for freezers are based upon a linear regression model using the following

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

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

[102] For example, the part-use factor that shall be applied to the current program year t (PYt) for savings verification purposes should be determined through the PYt-2 participant surveys conducted in the respective utility's service territory, if available. If an evaluation was not performed in PYt-2 the latest available evaluation should be used.

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

coefficients[104]:

Independent Variable Description	Estimate Coefficient
Intercept	132.122
Age (years)	12.130
Pre-1990 (=1 if manufactured pre-1990)	156.181
Size (cubic feet)	31.839
Chest Freezer Configuration (=1 if chest freezer)	-19.709
Interaction: Located in Unconditioned Space x CDD/365.25	9.778
Interaction: Located in Unconditioned Space x HDD/365.25	-12.755

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

Where:

Age = Age of retired unit

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

Size = Capacity (cubic feet) of retired unit

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

Interaction: Located in Unconditioned Space x CDD/365.25

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

CDD = Cooling Degree Days (see table above)

Interaction: Located in Unconditioned Space x HDD/365.25

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

HDD = Heating Degree Days (see table above)

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used[105]. . For illustration purposes, the example uses 0.85.[106]

The program averages for AIC's ARP PY4 program are used as an example.

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

= 977 * 0.825

= 905 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = kWh/8766 * CF

[104] Energy savings are based on an average 30-year TMY temperature of 51.1 degrees. Coefficients provided in January 31, 2013 memo from Cadmus: "Appliance Recycling Update".

[105] For example, the part-use factor that shall be applied to the current program year t (PYt) for savings verification purposes should be determined through the PYt-2 participant surveys conducted in the respective utility's service territory, if available. If an evaluation was not performed in PYt-2 the latest available evaluation should be used.

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

Where:

kWh = Savings provided in algorithm above

CF = Coincident factor defined as summer kW/average kW

= 1.081 for Refrigerators

= 1.028 for Freezers[107]

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

ΔkW = 806/8766 * 1.081

= 0.099 kW

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RFRC-V06-160601

REVIEW DEADLINE: 1/1/2022

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

5.1.9 Room Air Conditioner Recycling

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed remaining useful life of the existing room air conditioning unit being retired is 4 years[108].

DEEMED MEASURE COST

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

LOADSHAPE

Loadshape R08 - Residential Cooling

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 30%[109].

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

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

[109] Consistent with coincidence factors found 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)

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

= dependent on location[110]:

Climate Zone (City based upon)	FLH_{RoomAC}
1 (Rockford)	220
2 (Chicago)	210
3 (Springfield)	319
4 (Belleville)	428
5 (Marion)	374
Weighted Average[111]	248

Btu/H = Size of retired unit

= Actual. If unknown assume 8500 Btu/hr [112]

EERexist = Efficiency of existing unit

= 7.7[113]

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

ΔkWh = ((319 * 8500 * (1/7.7)) / 1000)

= 352 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (Btu/hr * (1/EERexist))/1000) * CF

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[114]

[110] 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 location (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) is 31%. This ratio is applied to those IL cities that have FLH for Central Cooling provided in the Energy Star calculator. For other cities this is extrapolated using the FLH assumptions VEIC have developed for Central AC. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
[111] Weighted based on number of residential occupied housing units in each zone.
[112] Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008
[113] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."
[114] Consistent with coincidence factors found 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)

For example an 8500 Btu/h unit:

$$\Delta kW = (8500 * (1/7.7)) / 1000) * 0.3$$

$$= 0.33 \text{ kW}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RARC-V01-120601

REVIEW DEADLINE: 1/1/2019

5.1.10 ENERGY STAR Clothes Dryer

Description

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR criteria. ENERGY STAR qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through 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[115]. 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[116].

Deemed Measure Cost

The incremental cost for an ENERGY STAR clothes dryer is assumed to be $152[117]

Loadshape

N/A

Coincidence Factor

The coincidence factor for this measure is 3.8%[118].

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[115] 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

[116] 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

[117] Based on the difference in installed cost for an efficient dryer ($716) and standard dryer ($564). http://www.aceee.org/files/proceedings/2012/data/papers/0193-000286.pdf

[118] Based on coincidence factor of 3.8% for clothes washers

Algorithm

Calculation of Energy Savings

Electric Energy Savings

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

Where:

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

Dryer Size	Load (lbs)[119]
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[120]. If product class unknown, assume electric, standard.

Product Class	CEF (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft^3)	3.11
Vented Electric, Compact (120V) (< 4.4 ft^3)	3.01
Vented Electric, Compact (240V) (<4.4 ft^3)	2.73
Ventless Electric, Compact (240V) (<4.4 ft^3)	2.13
Vented Gas	2.84[121]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.[122] If product class unknown, assume electric, standard.

Product Class	CEF (lbs/kWh)
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	3.93
Vented or Ventless Electric, Compact (120V) (< 4.4 ft^3)	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[123]

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year.[124]

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

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

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

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

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

[124] 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, 16% for gas dryers[125]

EXAMPLE

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

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

= 160 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer. Use actual data if available. If unknown, use 283 hours per year.[126]

CF = Summer Peak Coincidence Factor for measure

= 3.8%[127]

EXAMPLE

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

ΔkW = 160/283 * 3.8%

= 0.0215 kW

NATURAL GAS SAVINGS

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

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

Where:

Therm_convert = Conversion factor from kWh to Therm

= 0.03413

%Gas = Percent of overall savings coming from gas

= 0% for electric units and 84% for gas units[128]

---

[125] %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 16% was determined using a ratio of the electric to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

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

[127] Based on coincidence factor of 3.8% for clothes washers.

[128] %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.

EXAMPLE

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

$$\Delta Therm = (8.45/2.84 - 8.45/3.48) * 283 * 0.03413 * 0.84$$

$$= 4.44 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESDR-V01-150601

REVIEW DEADLINE: 1/1/2021

5.1.11 ENERGY STAR Water Coolers

Description

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The estimated useful life for a water cooler is 10 years[129].

Deemed Measure Cost

The incremental cost for this measure is estimated at $17[130].

Loadshape

Loadshape C53: Flat

Coincidence Factor

The summer peak coincidence factor is assumed to be 1.0.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

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

Where:

kWh_{base} = Daily energy use (kWh/day) for baseline water cooler[131]

Type of Water Cooler	kWh_{base}
Hot and Cold Water – Storage	1.090
Hot and Cold Water – On Demand	0.330

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

[131] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.

Type of Water Cooler	kWh_{base}
Cold Water Only	0.290

kWh_{ee} = Daily energy use (kWh/day) for ENERGY STAR water cooler[132]

Type of Water Cooler	kWh_{ee}
Hot and Cold Water – Storage	0.747
Hot and Cold Water – On Demand	0.170
Cold Water Only	0.157

Days = Number of days per year that the water cooler is in use
= 365.25 days[133]

Energy Savings:

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

DEMAND SAVINGS

ΔkW = ΔkWh / Hours * CF

Where:

Hours = Number of hours per year water cooler is in use
= 8766 hours[134]

CF = Summer Peak Coincidence Factor for measure

= 1.0

Demand Savings:

Type of Water Cooler	ΔkW
Hot and Cold Water - Storage	0.0143
Hot and Cold Water – On Demand	0.0067
Cold Water Only	0.0056

NATURAL GAS SAVINGS

N/A

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

132 Average kWh/day for from the ENERGY STAR efficient product database.

133 Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.

134 Assumed 365 days per year and 24 hours per day as utilized in daily energy consumption from ENERGY STAR Program Requirements Product Specification for Water Coolers Test Method.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-WTCL-V01-180101

REVIEW DEADLINE: 1/1/2024

5.2 Consumer Electronics End Use

5.2.1 Advanced Power Strip – Tier 1

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the advanced power strip is 7 years[135].

DEEMED MEASURE COST

For time of sale or new construction the incremental cost of an advanced Tier 1 power strip over a standard power strip with surge protection is assumed to be $10[136].

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

LOADSHAPE

Loadshape R13 - Residential Standby Losses – Entertainment

Loadshape R14 - Residential Standby Losses - Home Office

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 80%[137].

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

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

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = kWh * ISR

Where:

kWh = Assumed annual kWh savings per unit

= 56.5 kWh for 5-plug units or 103 kWh for 7-plug units[138]

ISR = In Service Rate, dependent on delivery mechanism

Delivery Mechanism	ISR
Energy Efficiency Kit	69%[139]
All other delivery mechanisms	100%

Using assumptions above:

# Plugs	Delivery Mechanism	ΔkWh
5- plug	Energy Efficiency Kit	39.0
	All other delivery mechanisms	56.5
7-plug	Energy Efficiency Kit	71.1
	All other delivery mechanisms	103.0
Unknown[140]	Energy Efficiency Kit	55.0
	All other delivery mechanisms	80.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW **=** ΔkWh / Hours * CF

Where:

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

= 7,129 [141]

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

[139] Average of Ameren Missouri, Potomac Edison, and PPL Electric ISR for smart strips in kits.
Cadmus, "Ameren Missouri RebateSavers Impact and Process Evaluation: Program Year 2013" p. 75.
Cadmus, "Process Evaluation Report, PPL Electric EE&C Plan, Program Year Five." p. 94
"Smart strip" in this context refers to the category of Advanced Power Strips, does not specifically signify Smart Strip® from BITS Limited, and was used without permission. Smart Strip® is a registered trademark of BITS Smart Strip, LLC.

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

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

CF = Summer Peak Coincidence Factor for measure

= 0.8 [142]

# Plugs	Delivery Mechanism	ΔkW
5- plug	Energy Efficiency Kit	0.0044
	All other delivery mechanisms	0.0063
7-plug	Energy Efficiency Kit	0.0080
	All other delivery mechanisms	0.0116
Unknown[143]	Energy Efficiency Kit	0.0062
	All other delivery mechanisms	0.0090

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-CEL-SSTR-V03-180101

REVIEW DEADLINE: 1/1/2021

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

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

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

Description

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

By utilizing advanced control strategies such as a countdown timer, external sensors (e.g. of infra-red remote usage and/or occupancy sensors, true RMS (Root Mean Square) power sensing; both active power loads and standby power loads of controlled devices are managed by Tier 2 AV APS devices[144]. Monitoring and controlling both active and standby power loads of controlled devices will reduce the overall load of a centralized group of electrical equipment (i.e. the home entertainment center). This more intelligent sensing and control process has been demonstrated to deliver increased energy savings and demand reduction compared with 'Tier 1 Advanced Power Strips'.

The Tier 2 APS market is a relatively new and developing one. With several new Tier 2 APS products coming to market, it is important that energy savings are clearly demonstrated through independent field trials. The IL Technical Advisory Committee have developed a protocol whereby product manufacturers must submit independent field trial evidence of the Energy Reduction Percentage of their particular product either to the TRM Administrator for consideration during the TRM update process (August – December), or engage with a Program Administrator's independent evaluation team to review at other times. The product will be assigned a Product Class (A-H) corresponding to the proven savings and all products in a class will claim consistent savings. The IL TRM Administrator will maintain a list of eligible product and class on the IL TRM Sharepoint site. If a mid-year review has taken place, supporting information should be posted on the Sharepoint site such that other program administrators can review.

Due to the inherent variance day to day and week to week for hours of use of AV systems, it is critical that field trial studies effectively address the variability in usage patterns. There is significant discussion in the EM&V and academic domain on the optimal methodology for controlling for these factors and in submitting evidence of energy savings, it is critical that it is demonstrated that these issues are adequately addressed.

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

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

Definition of Efficient Equipment

The efficient case is the use of a Tier 2 AV APS in a residential AV (home entertainment) environment that includes control of at least 2 AV devices with one being the television[145].

Only Tier 2 AV APS products that have independent demonstrated energy savings via field trials are eligible.

The minimum product specifications for Tier 2 AV APS are:

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[144] Tier 2 AV APS identify when people are not engaged with their AV equipment and then remove power, for example a TV and its peripheral devices that are unintentionally left on when a person leaves the house or for instance where someone falls asleep while watching television.

[145] Given this requirement, an AV environment consisting of a television and DVD player or a TV and home theater would be eligible for a Tier 2 AV APS installation.

Safety & longevity

- Product and installation instructions shall comply with 2012 International Fire Code and 2000 NFPA 101 Life Safety Code (IL Fire Code).
- Third party tested to all applicable UL Standards.
- Contains a resettable circuit breaker
- Incorporates power switching electromechanical relays rated for 100,000 switching cycles at full 15 amp load (equivalent to more than 10 years of use).

Energy efficiency functionality

- Calculates real power as the time average of the instantaneous power, where instantaneous power is the product of instantaneous voltage and current.
- Delivers a warning when the countdown timer begins before an active power down event and maintains the warning until countdown is concluded or reset by use of the remote or other specified signal
- Uses an automatically adjustable power switching threshold.

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The default deemed lifetime value for Tier 2 AV APS is assumed to be 7 years[146].

Deemed Measure Cost

Direct Installation: The actual installed cost (including labor) of the new Tier 2 AV APS equipment should be used.

Loadshape

Loadshape R13 - Residential Standby Losses – Entertainment

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 80%[147]

Algorithm

Calculation of Energy Savings

Electric Energy Savings

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

Where:

[146] There is little evaluation to base a lifetime estimate upon. Based on review of assumptions from other jurisdictions and the relative treatment of In Service Rates and persistence, an estimate of 7 years was agreed by the Technical Advisory Committee, but further evaluation is recommended.

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

ERP = Energy Reduction Percentage of qualifying Tier2 AV APS product range as provided below. See reference documents for Product Classification memo.

$BaselineEnergy_{AV}$ = 432 kWh[148]

Product Class	Field trial ERP range	ERP used	$BaselineEnergy_{AV}$ (kWh)
A	55 – 60%	55%	238
B	50 – 54%	50%	216
C	45 – 49%	45%	194
D	40 – 44%	40%	173
E	35 – 39%	35%	151
F	30 – 34%	30%	130
G	25 – 29%	25%	108
H	20 – 24%	20%	86

ISR = In Service Rate. See reference documents for Product Classification memo.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy savings as calculated above

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

= 4,380 [149]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [150]

NATURAL GAS SAVINGS

N/A[151]

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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[148] AESC, Inc, "Energy Savings of Tier 2 Advanced Power Strips in Residential AC Systems", p28. Note that this load represents the average *controlled* AV devices only and will likely be lower than total AC usage.

[149] This is estimate based on assumption that approximately half of savings are during active hours (supported by AESC study) (assumed to be 5.3 hrs/day, 1936 per year (NYSERDA 2011. "*Advanced Power Strip Research Report*")) and half during standby hours (8760-1936 = 6824 hours). The weighted average is 4380.

[150] In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes. This appears to be supported by the Average Weekday AV Demand Profile and Reduction charts in the AESC study (p33-34). These show that the average demand reduction is relatively flat.

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

MEASURE CODE: RS-CEL-APS2-V02-180101

REVIEW DEADLINE: 1/1/2019

5.3 HVAC End Use

5.3.1 Air Source Heat Pump

DESCRIPTION

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

This measure 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 (SEER 10 or under if present) systems from service, prior to its natural end of life, and replacement with a new high efficiency air source heat pump unit.

   Early Replacement determination will be based on meeting the following conditions:

   - The existing unit is operational when replaced, or
   - The existing unit requires minor repairs (<$276 per ton)[152].
   - All other conditions will be considered Time of Sale.

   The Baseline SEER of the existing unit replaced:

   - If the SEER of the existing unit is known and <=10, the Baseline SEER is the actual SEER value of the unit replaced. If the SEER is >10, the Baseline SEER = 14.
   - If the SEER of the existing unit is unknown use assumptions in variable list below (SEER_exist and HSPF_exist).
   - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown.[153]

Deemed Early Replacement Rates For ASHP

	Deemed Early Replacement Rate
Early Replacement Rate for ASHP participants	7%

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

[152] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[153] Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. This is used as a reasonable proxy for ASHP installations since ASHP specific data is not available. Report presented to Nicor Gas Company February 27, 2014, available at http://www.ilsag.info/evaluation-documents.html.

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.[154]

Remaining life of existing ASHP/CAC equipment is assumed to be 6 years[155] and 18 years for electric resistance.

Deemed Measure Cost

Time of sale: The incremental capital cost for this measure is dependent on the efficiency of the new unit[156].

Efficiency (SEER)	Incremental Cost ($/unit)
14.5	$123
15	$303
16	$438
17	$724
18	$724

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)[157]:

Efficiency (SEER)	Full Retrofit Cost (including labor)
14.5	$1,381 / ton + $123
15	$1,381 / ton + $303
16	$1,381 / ton + $438
17	$1,381 / ton + $724
18	$1,381 / ton + $724

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $1,518 per ton of capacity[158]. This cost should be discounted to present value using the nominal societal discount rate.

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[154] 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

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

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

[157] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com). See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation. Efficiency cost increment consistent with Cadmus study results.

[158] Ibid. $1381 per ton inflated using rate of 1.91%.

LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

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

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

= 72%[159]

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

= 46.6%[160]

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

= 67%[161]

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

= 28.5%

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

ΔkWh = ((FLH_cooling * Capacity_cooling * (1/SEER_base - 1/SEER_ee)) / 1000) + ((FLH_heat * Capacity_heating * (1/HSPF_base - 1/HSFP_ee)) / 1000)

Early replacement[162]:

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

= ((FLH_cooling * Capacity_cooling * (1/SEER_exist - 1/SEER_ee)) / 1000) + ((FLH_heat *

159 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

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

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

Capacity_heating * (1/HSPF_exist - 1/HSFP_ee)) / 1000)

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

= ((FLH_cooling * Capacity_cooling * (1/SEER_base - 1/SEER_ee)) / 1000) + ((FLH_heat * Capacity_heating * (1/HSPF_base - 1/HSFP_ee)) / 1000)

Where:

FLH_cooling = Full load hours of air conditioning

= dependent on location:

Climate Zone (City based upon)	FLH_cooling (single family) [163]	FLH_cooling (general multi family) [164]	FLH_cooling (weatherized multi family) [165]
1 (Rockford)	512	467	299
2 (Chicago)	570	506	324
3 (Springfield)	730	663	425
4 (Belleville)	1,035	940	603
5 (Marion)	903	820	526
Weighted Average[166]	629	564	362

Capacity_cooling = 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[167]
Air Source Heat Pump	9.12
Central AC	8.60
No central cooling[168]	Make '1/SEER_exist' = 0

SEER_base = Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)

= 14 [169]

SEER_ee = Seasonal Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/kWh)

163 Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

164 Ibid.

165 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. The multifamily units within this study had undergone significant shell improvements (air sealing and insulation) and therefore this set of assumptions is only appropriate for units that have recently participated in a weatherization or other shell program. Note that the FLHcool where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

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

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

168 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.

169 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.

= Actual

FLH_heat = Full load hours of heating

= Dependent on location and home type:

Climate Zone (City based upon)	FLH_heat (single family and general multi family)[170]	FLH heat (weatherized multi family)[171]
1 (Rockford)	1,969	748
2 (Chicago)	1,840	699
3 (Springfield)	1,754	667
4 (Belleville)	1,266	481
5 (Marion)	1,288	489
Weighted Average[172]	1,821	692

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

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

HSPF_exist =Heating System Performance Factor[173] 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 [174]
Electric Resistance	3.41[175]

HSPF_base =Heating System Performance Factor of baseline Air Source Heat Pump (kBtu/kWh)

= 8.2 [176]

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

(kBtu/kWh)

[170] Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the Energy Star Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider Energy Star estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from http://www.icc.illinois.gov/ags/consumereducation.aspx) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the Energy Star data (1994 hours) to scale down the Energy Star estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

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

[173] HSPF ratings for Heat Pumps account for the seasonal average efficiency of the units and are based on testing within zone 4 which encompasses most of Illinois. Furthermore, a recent Cadmus/Opinion Dynamics metering study, "Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)", found no significant variance between metered performance and that presented in the TRM

[174] 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.

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

[176] 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

= Actual

Time of Sale:

For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump installed in a single family home in Marion:

ΔkWh = ((903 * 36,000 * (1/14 - 1/15)) / 1000) + ((1,288 * 36,000 * (1/8.2 - 1/9)) / 1000)

= 657 kWh

Early Replacement:

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

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

= ((903 * 36,000 * (1/9.12 - 1/15)) / 1000) + ((1,288 * 36,000 * (1/5.44 - 1/9)) / 1000)

= 4769 kWh

ΔkWH for remaining measure life (next 12 years):

= ((903 * 36,000 * (1/14 - 1/15)) / 1000) + ((1,288 * 36,000 * (1/8.2 - 1/9)) / 1000)

= 657 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

ΔkW = (Capacity_cooling * (1/EER_base - 1/EER_ee)) / 1000) * CF

Early replacement[177]:

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

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

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

= ((Capacity_cooling * (1/EERbase - 1/EERee))/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) [178]

If SEER or EER rating unavailable use:

[177] 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).

[178] 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	EER_exist[179]
Air Source Heat Pump	8.55
Central AC	8.15
No central cooling[180]	Make '1/EER_exist' = 0

EER_base = Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/hr / kW)

= 11.8 [181]

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:[182]

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

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

= 72%%[183]

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

= 46.6%[184]

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

= 67%[185]

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

= 28.5%[35]

179 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
180 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.
181 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. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.
182 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.
183 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.
184 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
185 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015

Time of Sale:

For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump installed in single-family home in Marion:

ΔkW_{SSP} = ((36,000 * (1/11.8 – 1/12)) / 1000) * 0.72

= 0.037 kW

ΔkW_{PJM} = ((36,000 * (1/11.8 – 1/12)) / 1000) * 0.466

= 0.024 kW

Early Replacement:

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

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

= ((36,000 * (1/8.55 - 1/12)) / 1000) * 0.72

= 0.872 kW

ΔkW_{SSP} for remaining measure life (next 12 years):

= ((36,000 * (1/11.8 – 1/12)) / 1000) * 0.72

= 0.037 kW

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

= ((36,000 * (1/8.55 - 1/12)) / 1000) * 0.466

= 0.564 kW

ΔkW_{PJM} for remaining measure life (next 12 years):

= ((36,000 * (1/11.8 – 1/12)) / 1000) * 0.466

= 0.024 kW

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-V07-180101

REVIEW DEADLINE: 1/1/2021

5.3.2 Boiler Pipe Insulation

Description

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

The baseline is an un-insulated boiler pipe.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years[186].

Deemed Measure Cost

The measure cost including material and installation is assumed to be $3 per linear foot[187].

Loadshape

N/A

Coincidence Factor

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Savings

$$\Delta Therm = (((1/R_{exist} * C_{exist}) – (1/R_{new} * C_{new})) * FLH\_heat * L * \Delta T) / \eta Boiler /100,000$$

Where:

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

[186] 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

[187] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

= 0.5[188]

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

= Actual (0.5 + R value of insulation)

FLH_heat = Full load hours of heating

= Dependent on location[189]:

Climate Zone (City based upon)	FLH_heat
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[190]	1,821

L = Length of boiler pipe in unconditioned space covered by pipe wrap (ft)

= Actual

C_{exist} = Circumference of bare pipe (ft) (Diameter (in) * π/12)

= Actual (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)

C_{new} = Circumference of pipe with insulation (ft) ([Diameter of pipe (in)] + ([Thickness of Insulation (in)]*2)) * π/12)

= Actual

ΔT = Average temperature difference between circulated heated water and unconditioned space air temperature (°F) [191]

Pipes in unconditioned basement:

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

Pipes in crawl space:

[188] Assumption based on data obtained from the 3E Plus heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association) and derived from Table 15 and Table 16 of 2009 ASHRAE Fundamentals Handbook, Chapter 23 Insulation for Mechanical Systems, page 23.17.

[189] Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the Energy Star Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider Energy Star estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from http://www.icc.illinois.gov/ags/consumereducation.aspx) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the Energy Star data (1994 hours) to scale down the Energy Star estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

[191] Assumes 160°F water temp for a boiler without reset control, 120°F for a boiler with reset control, and 50°F air temperature for pipes in unconditioned basements and the following average heating season outdoor temperatures as the air temperature in crawl spaces: Zone 1 – 33.1, Zone 2 – 34.4, Zone 3 – 37.7, Zone 4 – 40.0, Zone 5 – 39.8, Weighted Average – 35.3 (NCDC 1881-2010 Normals, average of monthly averages Nov – Apr for zones 1-3 and Nov-March for zones 4 and 5).

Climate Zone (City based upon)	ΔT (°F)	
	Boiler without reset control	Boiler with reset control
1 (Rockford)	127	87
2 (Chicago)	126	86
3 (Springfield)	122	82
4 (Belleville)	120	80
5 (Marion)	120	80
Weighted Average[192]	125	85

ηBoiler = Efficiency of boiler

= 0.819 [193]

For example, insulating 10 feet of 0.75" pipe with R-3 wrap (0.75" thickness) in a crawl space of a Marion home with a boiler without reset control:

ΔTherm = (((1/0.5 * 0.196) – (1/3.5 * 0.589)) * 10 * 120 * 1288) / 0.819 / 100,000

= 4.2 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-PINS-V02-160601

REVIEW DEADLINE: 1/1/2022

[192] Weighted based on number of occupied residential housing units in each zone.
[193] Average efficiency of boiler units found in Ameren PY3-PY4 data.

5.3.3 Central Air Conditioning

DESCRIPTION

This measure characterizes:

a) Time of Sale:

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

b) Early Replacement:

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<$190 per ton)[194].
- All other conditions will be considered Time of Sale.

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

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

A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown[195].

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.

[194] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[195] 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 funaces. 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.

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; 14.5 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.

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[196] for the remainder of the measure life.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 18 years [197].

Remaining life of existing equipment is assumed to be 6 years[198].

Deemed Measure Cost

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below[199]:

Efficiency Level (SEER)	Incremental Cost
14	$0
15	$108
16	$221
17	$620
18	$620

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume defaults below[200].

Efficiency Level (SEER)	Full Retrofit Cost (including labor)
14	$952 / ton + $0
15	$952 / ton + $108
16	$952 / ton + $221
17	$952 / ton + $620
18	$952 / ton + $620

[196] Baseline SEER and EER should be updated when new minimum federal standards become effective.
[197] 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).
[198] Assumed to be one third of effective useful life
[199] Based on incremental cost results from Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016.
[200] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator, $2,857 (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). Efficiency cost increment consistent with Cadmus study results.

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be \$3,140[201]. This cost should be discounted to present value using the nominal societal discount rate.

LOADSHAPE

Loadshape R08 - Residential Cooling

COINCIDENCE FACTOR

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

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 68%[202]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 46.6%[203]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

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

Early replacement[204]:

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 and building type[205]:

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[201] 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.

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

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

[204] 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).

[205] Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency

Climate Zone (City based upon)	FLHcool (single family)	FLHcool (multi family)
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1035	940
5 (Marion)	903	820
Weighted Average[206]	629	564

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[207]

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

= 13[208]

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

= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 10.0[209].

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

= Actual installed or 14.5 if unknown

Time of sale example: a 3 ton unit with SEER rating of 14.5, in unknown location:

ΔkWH = (629 * 36,000 * (1/13 – 1/14.5)) / 1000

= 180 kWh

Early replacement example: a 3 ton unit, with SEER rating of 14.5 replaces an existing unit in unknown location:

ΔkWH(for first 6 years) = (629 * 36,000 * (1/10 – 1/14.5)) / 1000

= 702 kWh

ΔkWH(for next 12 years) = (629 * 36,000 * (1/13 – 1/14.5)) / 1000

= 180 kWh

Therefore savings adjustment of 26% (180/702) after 6 years.

Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

207 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.

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

209 VEIC 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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

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

Early replacement[210]:

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 [211]

EERexist = EER Efficiency of existing unit

= Actual EER of unit should be used, if EER is unknown, use 9.2[212]

EERee = EER Efficiency of ENERGY STAR unit

= Actual installed or 12 if unknown

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

= 68%[213]

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

= 46.6%[214]

[210] 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).

[211] 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).

[212] Based on SEER of 10,0, using formula above to give 9.2 EER.

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

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

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

ΔkW_{SSP} = (36,000 * (1/11.2– 1/12)) / 1000 * 0.68

= 0.146 kW

ΔkW_{PJM} = (36,000 * (1/11.2– 1/12)) / 1000 * 0.466

= 0.100 kW

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

ΔkW_{SSP} (for first 6 years) = (36,000 * (1/9.2– 1/12)) / 1000 * 0.68

= 0.621 kW

ΔkW_{SSP} (for next 12 years) = (36,000 * (1/11.2– 1/12)) / 1000 * 0.68

= 0.146 kW

ΔkW_{PJM} (for first 6 years) = (36,000 * (1/9.2– 1/12)) / 1000 * 0.466

= 0.425 kW

ΔkW_{PJM} (for next 12 years) = (36,000 * (1/11.2– 1/12)) / 1000 * 0.466

= 0.100 kW

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-CAC1-V07-180101

REVIEW DEADLINE: 1/1/2021

5.3.4 Duct Insulation and Sealing

DESCRIPTION

This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system.

Two methodologies for estimating the savings associate from sealing the ducts are provided. The first preferred method requires the use of a blower door and the second requires careful inspection of the duct work.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p.44 of the Energy Conservatory Blower Door Manual; which can be found on the Energy Conservatory website (As of Oct 2014: http://www.energyconservatory.com/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf)

2. **Evaluation of Distribution Efficiency** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table';

   http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf

   a. Percentage of duct work found within the conditioned space

   b. Duct leakage evaluation

   c. Duct insulation evaluation

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is sealed duct work throughout the unconditioned or semi-conditioned space in the home. A non-conditioned space is defined as a space outside of the thermal envelope of the building that is not intentionally heated for occupancy (crawl space, roof attic, etc). A semi-conditioned space is defined as a space within the thermal envelop that is not intentionally heated for occupancy (unfinished basement)[215].

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of this measure is 20 years[216].

DEEMED MEASURE COST

The actual duct sealing measure cost should be used.

LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

[215] Definition matches Regain factor discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012

[216] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

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

COINCIDENCE FACTOR

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

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

= 68%[217]

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

= 46.6%[218]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Modified Blower Door Subtraction

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

Where:

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

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

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

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

Where:

0.64 = Converts CFM50 to CFM25[219]

SLF = Supply Loss Factor

[217] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[218] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[219] 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual).

= % leaks sealed located in Supply ducts * 1 [220]

Default = 0.5[221]

RLF = Return Loss Factor

= % leaks sealed located in Return ducts * 0.5[222]

Default = 0.25[223]

c) Calculate Electric Energy Savings:

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

$\Delta kWh_{cooling}$ = $((\Delta CFM25_{DL} / ((CapacityCool/12{,}000) * 400)) * FLHcool * CapacityCool * TRFcool) / 1000 / \eta Cool$

ΔkWh_{Fan} = $(\Delta Therms * F_e * 29.3)$

Where:

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

= calculated above

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

=Actual

12,000 = Converts Btu/H capacity to tons

400 = Converts capacity in tons to CFM (400CFM / ton)[224]

FLHcool = Full load cooling hours

= Dependent on location as below[225]:

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940

[220] 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 http://www.energyconservatory.com/download/dbmanual.pdf

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

[222] 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 http://www.energyconservatory.com/download/dbmanual.pdf

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

[224] 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

[225] Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily
5 (Marion)	903	820
Weighted Average226	629	564

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.0 for Semi-Conditioned Spaces[227]

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume the following[228]:

Age of Equipment	SEER Estimate
Before 2006	10
After 2006 - 2014	13
Central AC After 1/1/2015	13
Heat Pump After 1/1/2015	14

ΔTherms = Therm savings as calculated in Natural Gas Savings

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

= 3.14%[229]

29.3 = kWh per therm

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

[227] Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[228] 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.

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

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

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

$CFM50_{Envelope\ Only}$ = 4500 CFM50

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

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

$CFM50_{Envelope\ Only}$ = 4500 CFM50

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

Duct Leakage:

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

= 387 CFM

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

= 139 CFM

Duct Leakage reduction at CFM25:

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

= 119 CFM25

Energy Savings:

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

= 237 + 195

= 432 kWh

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

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

Where:

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

=Actual

FLHheat = Full load heating hours

= Dependent on location as below[230]:

Climate Zone (City based upon)	FLH_heat
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754

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

Climate Zone (City based upon)	FLH_heat
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[231]	1,821

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[232]

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use[233]:

System Type	Age of Equipment	HSPF Estimate	COP Estimate
Heat Pump	Before 2006	6.8	2.00
	After 2006 - 2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00

3412 = Converts Btu to kWh

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

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

= 734 kWh

Methodology 2: Evaluation of Distribution Efficiency

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

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

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

[231] Weighted based on number of occupied residential housing units in each zone.
[232] Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.
[233] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

FLHcool = Full load cooling hours

= Dependent on location as below[234]:

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820
Weighted Average[235]	629	564

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

=Actual

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.0 for Semi-Conditioned Spaces[236]

1000 = Converts Btu to kBtu

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

= Actual. If unknown assume[237]:

Age of Equipment	SEER Estimate
Before 2006	10
After 2006 - 2014	13
Central AC After 1/1/2015	13
Heat Pump After 1/1/2015	14

[234] Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

[236] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[237] 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.

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

DE_{before} = 0.85

DE_{after} = 0.92

Energy Savings:

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

= 182 + 195

= 377 kWh

Heating savings for homes with electric heat:

$\Delta kWh_{heating}$ = ((DE_{after} – DE_{before})/ DE_{after})) * FLHheat * OutputCapacityHeat * TRFheat) / ηHeat / 3412

Where:

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

=Actual

FLHheat = Full load heating hours

= Dependent on location as below[238]:

Climate Zone (City based upon)	FLH_heat
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[239]	1,821

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[240]

COP = Coefficient of Performance of electric heating system[241]

= Actual. If not available use[242]:

[238] Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.
[239] Weighted based on number of occupied residential housing units in each zone.
[240] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.
[241] Note that the HSPF of a heat pump is equal to the COP * 3.413.
[242] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for

System Type	Age of Equipment	HSPF Estimate	COP Estimate
Heat Pump	Before 2006	6.8	2.00
	After 2006 - 2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00

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

DE_{after} = 0.92

DE_{before} = 0.85

Energy Savings:

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

= 563 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLHcool = Full load cooling hours:

= Dependent on location as below[243]:

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820
Weighted Average[244]	629	564

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

= 68%[245]

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

= 46.6%[246]

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.

243 Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

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

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

NATURAL GAS SAVINGS

For homes with Natural Gas Heating:

Methodology 1: Modified Blower Door Subtraction

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

Where:

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

InputCapacityHeat = Heating input capacity (Btu/hr)

=Actual

0.0123 = Conversion of Capacity to CFM (0.0123CFM / Btu/hr)[247]

FLHheat = Full load heating hours

=Dependent on location as below[248]:

Climate Zone (City based upon)	FLH_heat
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[249]	1,821

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[250]

100,000 = Converts Btu to therms

ηEquipment = Heating Equipment Efficiency

[247] 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, 24% of furnaces purchased in Illinois were condensing units. Therefore a weighted average required airflow rate is calculated assuming a 50:50 split of natural v induced draft non-condensing furnaces, as 123 per 10,000Btu or 0.0123/Btu.

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

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

[250] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

= Actual[251]. If not available use 83%[252]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[253]

= Actual. If not available use 70%[254]

[251] The Equipment Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.
If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

[252] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey: http://www.eia.gov/consumption/residential/data/2009/xls/HC6.9%20Space%20Heating%20in%20Midwest%20Region.xls))
In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) = 0.829

[253] 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.

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

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

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

$CFM50_{Envelope\ Only}$ = 4500CFM50

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

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

$CFM50_{Envelope\ Only}$ = 4500CFM50

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

Duct Leakage:

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

= 387 CFM

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

= 119 CFM

Duct Leakage reduction at CFM25:

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

= 119 CFM25

Energy Savings:

Pre Distribution Efficiency = 1 – (387/4800) = 92%

ηSystem = 80% * 92% = 74%

ΔTherm = ((119/ (105,000 * 0.0123)) * 1,754 * 105,000 * 1 *(0.8/0.74)) / 100,000

= 183 therms

Methodology 2: Evaluation of Distribution Efficiency

$$\Delta Therm = ((DE_{after} - DE_{before}) / DE_{after})) * FLHheat * InputCapacityHeat * TRFheat * (\eta Equipment / \eta System)) / 100,000$$

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

Other variables as defined above

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

DE_{after} = 0.92

DE_{before} = 0.85

Energy Savings:

ηSystem = 80% * 85% = 68%

ΔTherm = ((0.92 – 0.85)/0.92) * 1,754 * 105,000 * 1 * (0.8/0.68)) / 100,000

= 164 therm

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-DINS-V06-160601

REVIEW DEADLINE: 1/1/2022

5.3.5 Furnace 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.

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[255].

Deemed Measure Cost

The capital cost for this measure is assumed to be $97[256].

Loadshape

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

Coincidence Factor

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

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

= 68%[257]

[255] 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

[256] 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

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

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

= 46.6%[258]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = Heating Savings + Cooling Savings + Shoulder Season Savings

Where:

Heating Savings = Blower motor savings during heating season

= 418 kWh[259]

Cooling Savings = Blower motor savings during cooling season

If Central AC = 263 kWh

If No Central AC = 175 kWh

If unknown (weighted average)

= 241 kWh[260]

Shoulder Season Savings = Blower motor savings during shoulder seasons

= 51 kWh

For example, a blower motor in a home where Central AC presence is unknown:

ΔkWh = Heating Savings + Cooling Savings + Shoulder Season Savings

= 418 +263 + 51

= 732 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Cooling Savings / FLH_cooling * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[261]:

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

259 To estimate heating, cooling and shoulder season savings for Illinois, VEIC adapted 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 to account for different run hour assumptions (average values used) for Illinois. See: FOE to IL Blower Savings.xlsx.

260 The weighted average value is based on assumption that 75% of homes installing BPM furnace blower motors have Central AC. 66% of IL housing units have CAC and 66% have gas furnaces. It is logical these two groups overlap to a large extent (like the 95% in the FOE study above).

261 Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency

Climate Zone (City based upon)	FLH_cooling
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903
Weighted Average[262]	629

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

= 68%[263]

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

= 46.6%[264]

For example, a blower motor in a home of unknown location where Central AC prevalence is unknown:

ΔkW_{SSP} = 251 / 629 * 0.68

= 0.271 kW

ΔkW_{SSP} = 251 / 629 * 0.466

= 0.186 kW

NATURAL GAS SAVINGS

Δtherms[265] = - Heating Savings * 0.03412/ AFUE

Where:

0.03412 = Converts kWh to therms

AFUE = Efficiency of the Furnace

= Actual. If unknown assume 95%[266] if in new furnace or 64.4 AFUE% [267] if in existing furnace

Using defaults:

For new Furnace = - (418 * 0.03412) / 0.95

= - 15.0 therms

For existing Furnace = - (418 * 0.03412) / 0.644

Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

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

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

265 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.

266 Minimum ENERGY STAR efficiency after 2.1.2012.

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

= - 22.1 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-FBMT-V03-150601

REVIEW DEADLINE: 1/1/2020

5.3.6 Gas High Efficiency Boiler

Description

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

This measure characterizes:

a) Time of Sale:

   a. The installation of a new high efficiency, gas-fired hot water boiler in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

   Early Replacement determination will be based on meeting the following conditions:

   - The existing unit is operational when replaced, or
   - The existing unit requires minor repairs (<$709)[268].
   - All other conditions will be considered Time of Sale.

   The Baseline AFUE of the existing unit replaced:

   - If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 82%.
   - If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
   - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown[269].

Deemed Early Replacement Rates For Boilers

	Deemed Early Replacement Rate
Early Replacement Rate for Boiler participants	7%

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

Definition of Efficient Equipment

To qualify for this measure the installed Boiler must be ENERGY STAR qualified (AFUE rated at or greater than 85% and input capacity less than 300,000 Btu/hr).

[268] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[269] Based upon research from "Home Energy Efficiency Rebate Program GPY2 Evaluation Report" which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. This is used as a reasonable proxy for boiler installations since boiler specific data is not available. Report presented to Nicor Gas Company February 27, 2014, available at http://www.ilsag.info/evaluation-documents.html.

DEFINITION OF BASELINE EQUIPMENT

Time of sale: The baseline equipment for this measure is a new, gas-fired, standard-efficiency water boiler. The current Federal Standard minimum is 82% AFUE.

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years[270].

Early replacement: Remaining life of existing equipment is assumed to be 8 years[271].

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is dependent on tier[272]:

Measure Type	Installation Cost	Incremental Install Cost
AFUE 82%	$3543	n/a
AFUE 85% (Energy Star Minimum)	$4268	$725
AFUE 90%	$4815	$1,272
AFUE 95%	$5328	$1,785

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $4,045[273]. This cost should be discounted to present value using the nominal discount rate.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

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[270] 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

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

[272] Based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf). Where efficiency ratings are not provided, the values are interpolated from those that are.

[273] $3543 inflated using 1.91% rate.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Time of Sale:

ΔTherms = Gas_Boiler_Load * HF * (1/AFUE(base) - 1/AFUE(eff))

Early replacement[274]:

ΔTherms for remaining life of existing unit (1st 8 years):

= Gas_Boiler_Load * HF * (1/AFUE(exist) - 1/AFUE(eff)))

ΔTherms for remaining measure life (next 17 years):

= Gas_Boiler_Load * HF * (1/AFUE(base) - 1/AFUE(eff)))

Where:

Gas_Boiler_Load[275] = Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below[276].

= or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[277].

Climate Zone (City based upon)	Gas_Boiler Load (therms)
1 (Rockford)	1275
2 (Chicago)	1218
3 (Springfield)	1043
4 (Belleville)	805
5 (Marion)	819
Average	1158

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

Household Type	HF
Single-Family	100%

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[274] 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).

[275] Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Heating load is used to describe the household heating need, which is equal to (gas heating consumption * AFUE)

[276] Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[277] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations should be completed by contractors during the selection process and may be readily available for program data purposes.

Household Type	HF
Multi-Family	65%[278]
Actual	Custom[279]

AFUE(exist) = Existing Boiler Annual Fuel Utilization Efficiency Rating

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

If unknown, assume 61.6 AFUE% [280].

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

= 82%

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

= Actual. If unknown, use defaults dependent[281] on tier as listed below:

Measure Type	AFUE(eff)
ENERGY STAR®	87.5%
AFUE 90%	92.5%
AFUE 95%	95%

Time of Sale:

For example, a default sized ENERGY STAR boiler purchased and installed near Springfield

ΔTherms = 1043 * (1/0.82 - 1/0.875)

= 80.0 Therms

Early Replacement:

For example, an existing function boiler with unknown efficiency is replaced with an ENERGY STAR boiler purchased and installed in Springfield.

ΔTherms for remaining life of existing unit (1st 8 years):

= 1043 * (1/0.616 – 1/0.875)

= 501 Therms

ΔTherms for remaining measure life (next 17 years):

= (1043) * (1/0.82 - 1/0.875)

= 80.0 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

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

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

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

[281] Default values per tier selected based upon the average AFUE value for the tier range except for the top tier where the minimum is used due to proximity to the maximum possible.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GHEB-V06-180101

REVIEW DEADLINE: 1/1/2021

5.3.7 Gas High Efficiency Furnace

DESCRIPTION

High efficiency furnace features may include improved heat exchangers and modulating multi-stage burners.

This measure characterizes:

a) Time of sale:

  a. The installation of a new high efficiency, gas-fired condensing furnace in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

  Early Replacement determination will be based on meeting the following conditions:

  - The existing unit is operational when replaced, or
  - The existing unit requires minor repairs (<$528)[282].
  - All other conditions will be considered Time of Sale.

  The Baseline AFUE of the existing unit replaced:

  - If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
  - If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
  - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

  A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown[283].

Deemed Early Replacement Rates For Furnaces

Replacement Scenario for the Furnace	Deemed Early Replacement Rate
Early Replacement Rate for Furnace-only participants	7%
Early Replacement Rate for a furnace when the furnace is the Primary unit in a Combined System Replacement (CSR) project	14%
Early Replacement Rate for a furnace when the furnace is the Secondary unit in a CSR project	46%

Verified Quality Installation

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and

[282] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[283] 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 funaces. 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.

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. We estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years[284].

For early replacement: Remaining life of existing equipment is assumed to be 6 years[285].

Deemed Measure Cost

Time of sale: The incremental installed cost (retail equipment cost plus installation cost) for this measure depends on efficiency as listed below[286]:

AFUE	Installed Cost	Incremental Installed Cost
80%	$2011	n/a
90%	$2641	$630
91%	$2727	$716
92%	$2813	$802
93%	$3025	$1014
94%	$3237	$1226
95%	$3449	$1438
96%	$3661	$1650

Early Replacement: The full installed cost is provided in the table above. The assumed deferred cost (after 6 years)

[284] 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

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

[286] Based on data from Table E.1.1 of Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor.(http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf). Where efficiency ratings are not provided, the values are interpolated from those that are. Note that ECM furnace fan cost (refer to other measure in TRM) has been deducted from the 93%-96% AFUE values to avoid double counting.

of replacing existing equipment with a new 90% baseline unit is assumed to be $2903[287]. This cost should be discounted to present value using the nominal discount rate.

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

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

NATURAL GAS SAVINGS

Time of Sale:

ΔTherms = Gas_Furnace_Heating_Load * HF * ((1/(AFUE(base)*(1-Derating(base)))) – (1/(AFUE(eff)*(1-Derating(eff)))))

Early replacement[288]:

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

= Gas_Furnace_Heating_Load * HF * ((1/(AFUE(exist)*(1-Derating(exist)))) – (1/(AFUE(eff)*(1-Derating(eff)))))

ΔTherms for remaining measure life (next 14 years):

= Gas_Furnace_Heating_Load * HF * ((1/(AFUE(base)*(1-Derating(base)))) – (1/(AFUE(eff)*(1-Derating(eff)))))

Where:

Gas_Furnace_Heating_Load

[287] $2641 inflated using 1.91% rate.

[288] 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).

= Estimate of annual household heating load [289] for gas furnace heated single-family homes. If location is unknown, assume the average below[290].

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[291].

Climate Zone (City based upon)	Gas_Furnace_Heating_Load (therms)
1 (Rockford)	873
2 (Chicago)	834
3 (Springfield)	714
4 (Belleville)	551
5 (Marion)	561
Average	793

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

Household Type	HF
Single-Family	100%
Multi-Family	65%[292]
Actual	Custom[293]

AFUE(exist) = Existing Furnace Annual Fuel Utilization Efficiency Rating

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

If unknown, assume 64.4 AFUE% [294].

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

= Dependent on program type as listed below[295]:

Program Year	AFUE(base)
Time of Sale	80%
Early Replacement [296]	90%

[289] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE)
[290] Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.
[291] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.
[292] Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% factor is applied to MF homes based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes
[293] Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.
[294] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
[295] Though the Federal Minimum AFUE is 78%, there were only 50 models listed in the AHRI database at that level. At AFUE 79% the total rises to 308. There are 3,548 active furnace models listed with AFUE ratings between 78 and 80.
[296] We estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.

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

= Actual. If unknown, assume 95%[297]

Derating(base) =Baseline furnace AFUE derating

= 6.4%[298]

Derating(eff) =Efficent furnace AFUE derating

=0% if verified quality installation is performed

=6.4% if verified quality installation is not performed[299]

Time of Sale:

For example, a 95% AFUE furnace purchased and installed with verified quality installation for an existing home near Rockford:

ΔTherms = 873 * ((1/(0.8*(1-6.4%))) – (1/(0.95*(1-0%))))

=247 therms

For example, a 95% AFUE furnace purchased and installed without verified quality installation for an existing home near Rockford:

ΔTherms = 873 * ((1/(0.8*(1-6.4%))) – (1/(0.95*(1-6.4%))))

=184 therms

Early Replacement:

For example, an existing functioning furnace with unknown efficiency is replaced with an 95% furnace using quality installation in Rockford:

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

= 873 * ((1/(0.644*(1-6.4%))) – (1/(0.95*(1-0%))))

= 529 therms

ΔTherms for remaining measure life (next 14 years):

= 873 * ((1/(0.9*(1-6.4%))) – (1/(0.95*(1-0%))))

=117 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[297] Minimum ENERGY STAR efficiency after 2.1.2012.

[298] Brand, L., Yee, S., and Baker, J. "Improving Gas Furnace Performance: A Field and Laboratory Study at End of Life." Building Technologies Office. National Renewable Energy Laboratory. 2015 http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/improving-gas-furnace-performance.pdf, accessed September 6th, 2016, DOE/GO--102015-4624

[299] Ibid

MEASURE CODE: RS-HVC-GHEF-V07-180101

REVIEW DEADLINE: 1/1/2021

5.3.8 Ground Source Heat Pump

DESCRIPTION

This measure characterizes the installation of a Ground Source Heat Pump under the following scenarios:

a) New Construction:

   i. The installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new home.
   ii. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

b) Time of Sale:

   i. The planned installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   ii. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.

c) Early Replacement/Retrofit:

   i. The early removal of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   ii. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   iv. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced, or
      - The existing unit requires minor repairs, defined as costing less than[300]:

Existing System	Maximum repair cost
Air Source Heat Pump	$276 per ton
Central Air Conditioner	$190 per ton
Boiler	$709
Furnace	$528
Ground Source Heat Pump	<$249 per ton

      - All other conditions will be considered Time of Sale.

   v. The Baseline efficiency of the existing unit replaced:
      - If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the "New Baseline" column below:

Existing System	Maximum efficiency for Actual	New Baseline
Air Source Heat Pump	10 SEER	14 SEER

[300] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement.

Existing System	Maximum efficiency for Actual	New Baseline
Central Air Conditioner	10 SEER	13 SEER
Boiler	75% AFUE	82% AFUE
Furnace	75% AFUE	80% AFUE
Ground Source Heat Pump	10 SEER	13 SEER

- If the efficiency of the existing unit is unknown, use assumptions in variable list below (SEER, HSPF or AFUE exist).
- If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment must be a Ground Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed below:

ENERGY STAR Requirements (Effective January 1, 2012)

Product Type	Cooling EER	Heating COP
Water-to-air		
Closed Loop	17.1	3.6
Open Loop	21.1	4.1
Water-to-Water		
Closed Loop	16.1	3.1
Open Loop	20.1	3.5
DGX	16	3.6

DEFINITION OF BASELINE EQUIPMENT

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

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8[301] EER and a Federal Standard electric hot water heater.

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER. If a gas water heater, the Federal Standard baseline is calculated as follows[302]; for <=55 gallon tanks = 0.675 – (0.0015 * storage size in gallons) and for tanks >55 gallon = 0.8012 – (0.00078 * storage size in gallons). For a 40-gallon storage water heater this would be 0.615 EF.

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit,

[301] 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. Masters Thesis, University of Colorado at Boulder.
[302] Minimum Federal Standard as of 4/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

meeting the baselines provided below.

Unit Type	Efficiency Standard
ASHP	14 SEER, 11.8 EER, 8.2 HSPF
Gas Furnace	80% AFUE
Gas Boiler	82% AFUE
Central AC	13 SEER, 11 EER

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years[303].

For early replacement, the remaining life of existing equipment is assumed to be 8 years[304].

DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump should be used (default of $3957 per ton[305]), minus the assumed installation cost of the baseline equipment ($1381 per ton for ASHP[306] or $2011 for a new baseline 80% AFUE furnace or $3543 for a new 82% AFUE boiler[307] and $952 per ton[308] for new baseline Central AC replacement).

Early Replacement: The full installation cost of the Ground Source Heat Pump should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and 1,047 per ton for new baseline Central AC replacement[309]. This future cost should be discounted to present value using the nominal societal discount rate.

LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling	(if replacing gas heat and central AC)[310]
Loadshape R09 - Residential Electric Space Heat	(if replacing electric heat with no cooling)
Loadshape R10 - Residential Electric Heating and Cooling	(if replacing ASHP)

[303] System life of indoor components as per DOE estimate http://energy.gov/energysaver/articles/geothermal-heat-pumps. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

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

[305] Based on data provided in 'Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives'.

[306] Based on data provided on Home Advisor website, providing national average ASHP cost based on 2465 cost submittals. http://www.homeadvisor.com/cost/heating-and-cooling/install-a-heat-pump/

[307] Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf). Where efficiency ratings are not provided, the values are interpolated from those that are.

[308] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls).

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

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

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

Coincidence Factor

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

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

= 72%%[311]

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

= 46.6%[312]

Algorithm

Calculation of Savings

Electric Energy Savings

New Construction and Time of Sale (non-fuel switch only):

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/$SEER_{base}$– 1/EER_{PL})/1000] + [Elecheat * FLHheat * Capacity_heating * (1/$HSPF_{base}$ – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh = [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/EER_{PL})/1000] + [FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

Early replacement (non-fuel switch only)[313]:

ΔkWH for remaining life of existing unit (1st 8 years):

[311] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'. http://www.icc.illinois.gov/downloads/public/edocket/368522.pdf

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

[313] 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).

= [Cooling savings] + [Heating savings] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/SEERexist – 1/EER_{PL})/1000] + [ElecHeat * FLHheat * Capacity_heating * (1/HSPFexist – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

ΔkWH for remaining measure life (next 17 years):

= [FLHcool * Capacity_cooling * (1/SEERbase – 1/EER_{PL})/1000] + [ElecHeat * FLHheat * Capacity_heating * (1/HSPFbase – (1/(COP_{PL} * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

Early replacement - fuel switch only (see illustrative examples after Natural Gas section):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/SEERexist – 1/EER_{PL})/1000] + [FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/EER_{PL})/1000] + [FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

Where:

FLHcool = Full load cooling hours

Dependent on location as below[314]:

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820
Weighted Average[315]	629	564

Capacity_cooling = Cooling Capacity of Ground Source Heat Pump (Btu/hr)

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

SEERbase = SEER Efficiency of new replacement baseline unit

[314] Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
[315] Weighted based on number of occupied residential housing units in each zone.

Existing Cooling System	SEERbase
Air Source Heat Pump	14[316]
Central AC	13[317]
No central cooling	13[318]

SEERexist = SEER Efficiency of existing cooling unit

= Use actual SEER rating where it is possible to measure or reasonably estimate, if unknown assume default provided below:

Existing Cooling System	SEER_exist
Air Source Heat Pump	9.12[319]
Central AC	8.60[320]
No central cooling	13 [321]

$SEER_{ASHP}$ = SEER Efficiency of new baseline Air Source Heat Pump unit (for fuel switch)

= 14 [322]

EER_{PL} = Part Load EER Efficiency of efficient GSHP unit[323]

= Actual installed

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

FLHheat = Full load heating hours

Dependent on location as below[324]:

Climate Zone (City based upon)	FLH_heat
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288
Weighted Average[325]	1,821

316 Minimum Federal Standard as of 1/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf
317 Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
318 Assumes that the decision to replace existing systems includes desire to add cooling.
319 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
320 Ibid.
321 Assumes that the decision to replace existing systems includes desire to add cooling.
322 Minimum Federal Standard as of 1/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf
323 As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.
324 Heating EFLH based on ENERGY STAR EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
325 Weighted based on number of occupied residential housing units in each zone.

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

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

$HSPF_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

Existing Heating System	HSPF_base
Air Source Heat Pump	8.2
Electric Resistance	3.41[326]

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 unknown assume default:

Existing Heating System	HSPF_exist
Air Source Heat Pump	5.44
Electric Resistance	3.41

$HSPF_{ASHP}$ =Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)

=8.2 [327]

COP_{PL} = Part Load Coefficient of Performance of efficient unit[328]

= Actual Installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).

ElecDHW = 1 if existing DHW is electrically heated

= 0 if existing DHW is not electrically heated

%DHWDisplaced = Percentage of total DHW load that the GSHP will provide

= Actual if known

= If unknown and if desuperheater installed assume 44%[329]

= 0% if no desuperheater installed

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

= Actual. If unknown or for new construction assume federal standard[330]:

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

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

326 Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
327 Minimum Federal Standard as of 1/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf
328 As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.
329 Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 * 2/3 = 44%). Based on input from Doug Dougherty, Geothermal Exchange Organization.
330 Minimum Federal Standard as of 4/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[331]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[332]
Custom	Actual Occupancy or Number of Bedrooms[333]

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= 125°F

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

= 54°F[334]

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

3412 = Conversion from Btu to kWh

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

[332] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[333] 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.

[334] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

Illustrative Examples

New Construction using ASHP baseline:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed with a 50 gallon electric water heater in single family house in Springfield:

ΔkWh = [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/EER_{PL})/1000] + [FLHheat * Capacity_heating * (1/HSPFbase – 1/(COP_{PL} * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

ΔkWh = [730 * 36,000 * (1/14 – 1/19) / 1000] + [1754* 36,000 * (1/8.2 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 494 + 3494 + 1328

= 5316 kWh

Early Replacement – non-fuel switch (see example after Natural gas section for Fuel switch):

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed in single family house in Springfield with a 50 gallon electric water heater replacing an existing working Air Source Heat Pump with unknown efficiency ratings:

ΔkWH for remaining life of existing unit (1st 8 years):

= [730 * 36,000 * (1/9.12 - 1/19) / 1000] + [1754 * 36,000 * (1/5.44 - 1/(4.4 * 3.412)) / 1000] + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 1498 + 7401 + 1328

= 10,227 kWh

ΔkWH for remaining measure life (next 17 years):

= (730 * 36,000 * (1/14 – 1/28) / 1000] + [1967 * 36,000 * (1/8.2 – 1/ (4.4 * 3.412)) / 1000] + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 494 + 3494 + 1328

= 5316 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

New Construction and Time of Sale:

ΔkW = (Capacity_cooling * (1/EERbase - 1/EER_{FL}))/1000 * CF

Early replacement:

ΔkW for remaining life of existing unit (1st 8 years):

= (Capacity_cooling * (1/EERexist - 1/EER_{FL}))/1000 * CF

ΔkW for remaining measure life (next 17 years):

= (Capacity_cooling * (1/EERbase - 1/EER_{FL}))/1000 * CF

Where:

EERbase = EER Efficiency of new replacement unit

Existing Cooling System	EER_base
Air Source Heat Pump	11.8[335]
Central AC	11 [336]
No central cooling	11[337]

EERexist = Energy Efficiency Ratio of existing cooling unit (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:

$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$ [338]

If SEER rating unavailable use:

Existing Cooling System	EER_exist
Air Source Heat Pump	8.55
Central AC	8.15[340]
No central cooling	11 [341]

EER_{FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit [342]

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

= 72%%[343]

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

= 46.6%[344]

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

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

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

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

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

340 Ibid.

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

342 As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP.

343 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'. http://www.icc.illinois.gov/downloads/public/edocket/368522.pdf

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

New Construction or Time of Sale:

For example, a 3 ton unit with Full Load EER rating of 19:

ΔkW_{SSP} = (36,000 * (1/11.8 – 1/19))/1000 * 0.72

= 0.83 kW

ΔkW_{PJM} = (36,000 * (1/11 – 1/19))/1000 * 0.466

= 0.54 kW

Early Replacement:

For example, a 3 ton Full Load 19 EER replaces an existing working Air Source Heat Pump with unknown efficiency ratings in Marion:

ΔkW_{SSP} for remaining life of existing unit (1st 8 years):

= (36,000 * (1/8.55 – 1/19))/1000 * 0.72

= 1.67 kW

ΔkW_{SSP} for remaining measure life (next 17 years):

= (36,000 * (1/11.8 – 1/19))/1000 * 0.72

= 0.83 kW

ΔkW_{PJM} for remaining life of existing unit (1st 8 years):

= (36,000 * (1/8.55 – 1/19))/1000 * 0.466

= 1.08 kW

ΔkW_{PJM} for remaining measure life (next 17 years):

= (36,000 * (1/11.8 – 1/19))/1000 * 0.466

= 0.54 kW

NATURAL GAS SAVINGS

New Construction and Time of Sale with baseline gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat * Capacity_heating * 1/(COP_{PL} * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below, (electric savings is provided in Electric Energy Savings section):

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat *

Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

Early replacement for homes with existing gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/(COP_{PL} * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/(COP_{PL} * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

Gas_Heating_Load

= Estimate of annual household heating load [345] for gas furnace heated single-family homes. If location is unknown, assume the average below.

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[346].

[345] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE)

[346] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.

Climate Zone (City based upon)	Gas_Heating_Load if Furnace (therms) [347]	Gas_Heating_Load if Boiler (therms) [348]
1 (Rockford)	873	1275
2 (Chicago)	834	1218
3 (Springfield)	714	1043
4 (Belleville)	551	805
5 (Marion)	561	819
Average	793	1158

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating

= 80% if furnace and 82% if boiler.

AFUEexist = Existing Annual Fuel Utilization Efficiency Rating

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

If unknown, assume 64.4% if furnace and 61.6% [349] if boiler.

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

= 90%[350] if furnace and 82% if boiler.

kWhtoTherm = Converts source kWh to Therms

= H_{grid} / 100000

H_{grid} = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[351]. Also include any line losses.

For systems operating more than 6,500 hrs per year:

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347 Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

348 Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

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

350 Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced.

351 Refer to EPA eGRID data http://www.epa.gov/chp/documents/fuel_and_co2_savings.pdf, page 24 and http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Summary_Tables.pdf, page 9. Current values are:

- Non-Baseload RFC West: 9,811 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 10,511 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 10,038 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 10,364 Btu/kWh * (1 + Line Losses)

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

3.412 = Converts COP to HSPF

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

= Actual. If unknown assume federal standard[352]:

For <=55 gallons: 0.675 – (0.0015 * tank_size)

For > 55 gallons 0.8012 – (0.00078 * tank size)

= If tank size unknown assume 40 gallons and EF_Baseline of 0.615

All other variables provided above

[352] Minimum Federal Standard as of 4/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

Illustrative Examples *[for illustrative purposes a Heat Rate of 10,000 Btu/kWh is used]*

New construction using gas furnace and central AC baseline, *supported by Gas utility only*:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater is installed in place of a natural gas furnace and 3 ton Central AC unit:

ΔkWH = 0

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat * Capacity_heating * 1/(COP_{PL} * 3.412)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

= [(1-0) * ((714/0.80) – (10000/100000 * 1754 * 36,000 * 1/(4.4 * 3.412))/1000)] + [(1 – 0) * (0.44 * (1/ 0.615 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]

= 472 + 70

= 542 therms

Early Replacement fuel switch, *supported by gas and electric utility*:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [(FLHcool * Capacity_cooling * (1/SEERexist – (1/EER_{PL})/1000] + [(FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – (1/COP_{PL} * 3.412)))/1000] + [ElecDHW * %DHWDisplaced * (((1/ EF_{ELEC}) * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

= [(730* 36,000 * (1/8.6 - 1/19)) / 1000] + [(1754 * 36,000 * (1/8.2 - 1/(4.4 * 3.412))) / 1000] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 1673 + 3494 + 0

= 5167 kWh

Continued on next page.

Illustrative Example continued

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings] + [DHW savings]

= [(FLHcool * Capacity_cooling * (1/$SEER_{base}$ – (1/EER_{PL})/1000] + [(FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – (1/COP_{PL} * 3.412)))/1000] + [ElecDHW * %DHWDisplaced * (((1/ EF_{ELEC}) * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) /3412)]

= [(730 * 36,000 * (1/13 – 1/19)) / 1000] + [1754 * 36,000 * (1/8.2 – 1/ (4.4 *3.412)) / 1000] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) *1)/3412)]

= 638 + 3494 + 0

= 4132 kWh

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

= [(1-0) * ((714/0.644) – (10000/100000 * 1754 * 36,000 * 1/8.2)/1000)] + [(1 – 0) * (0.44 * (1/ 0.615 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]

= 339 + 70

= 408 therms

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

= [(1-0) * ((714/0.9) – (10000/100000 * 1754 * 36,000 * 1/8.2)/1000)] + [(1 – 0) * (0.44 * (1/ 0.615 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]

= 23 + 70

= 93 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch GSHP projects per Section 16-111.5B, changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[353]] + [DHW Savings if gas]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

ΔkWh = - [GSHP heating consumption] + [Cooling savings[354]] + [DHW savings if electric]

= - [(FLHheat * Capacity_heating * (1/COP_{PL} * 3.412))/1000] + [(FLHcool * Capacity_cooling * (1/SEERbase - 1/EER_{PL}))/1000] + [ElecDHW * %DHWDisplaced * ((1/EF_{ELEC} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 9-25)]:

ΔTherms = [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]

= [(1-0) * (714/0.644)] + [((1 – 0) * 0.44 * (1/ 0.615 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]

= 1109 + 70

= 1179 therms

ΔkWh = - [(FLHheat * Capacity_heating * (1/COP_{PL} * 3.412))/1000] + [(FLHcool * Capacity_cooling * (1/SEERexist - 1/EER_{PL}))/1000] + [ElecDHW * %DHWDisplaced * (((1/EF_{ELEC}) * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412)]

= - [(1754 * 36,000 * (1/(4.4 * 3.412)))/ 1000] + [(730 * 36,000 * (1/8.6 - 1/19))/ 1000)] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= -4206 + 1673 + 0

= -2533 kWh

[353] Note AFUEbase in the algorithm should be replaced with AFUEexist for early replacement measures.

[354] Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures.

MEASURE CODE: RS-HVC-GSHP-V07-180101

REVIEW DEADLINE: 1/1/2021

5.3.9 High Efficiency Bathroom Exhaust Fan

Description

This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 50 CFM rated at a sound level of less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

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

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

Definition of Efficient Equipment

New efficient (average CFM/watt of 8.3 [355]) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate indicated by ASHRAE 62.2[356]

Definition of Baseline Equipment

New standard efficiency (average CFM/Watt of 3.1[357]) exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2 [358]

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 19 years[359].

Deemed Measure Cost

Incremental cost per installed fan is $43.50 for quiet, efficient fans[360].

Loadshape

Loadshape R11 - Residential Ventilation

Coincidence Factor

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

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355 VEIC analysis looking at average efficient fan (i.e. Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.
356 Bi-level controls may be used by efficient fans larger than 50 CFM
357 VEIC analysis looking at average baseline fan (i.e. non-Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.
358 On/off cycling controls may be required of baseline fans larger than 50CFM.
359 Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.
360 VEIC analysis using cost data collected from wholesale vendor; http://www.westsidewholesale.com/ .

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = (CFM * (1/\eta_{,BASELINE} - 1/\eta_{EFFICIENT})/1000) * Hours$

Where:

CFM = Nominal Capacity of the exhaust fan

= 50 CFM[361]

$\eta_{BASELINE}$ = Average efficacy for baseline fan

= 3.1 CFM/Watt[362]

$\eta_{EFFCIENT}$ = Average efficacy for efficient fan

= 8.3 CFM/Watt[363]

Hours = assumed annual run hours,

= 8766 for continuous ventilation.

$\Delta kWh = (50 * (1/3.1 – 1/8.3)/1000) * 8766$

$= 88.6 \text{ kWh}$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor

= 1.0 (continuous operation)

Other variables as defined above

$\Delta kW = (50 * (1/3.1 – 1/8.3)/1000) * 1.0$

$= 0.0101 \text{ kW}$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[361] 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.

[362] VEIC analysis looking at average baseline fan (i.e. non-Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

[363] VEIC analysis looking at average efficient fan (i.e. Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-BAFA-V01-120601

REVIEW DEADLINE: 1/1/2019

5.3.10 HVAC Tune Up (Central Air Conditioning or Air Source Heat Pump)

Description

This measure involves the measurement of refrigerant charge levels and airflow over the central air conditioning or heat pump unit coil, correction of any problems found and post-treatment re-measurement. Measurements must be performed with standard industry tools and the results tracked by the efficiency program.

Savings from this measure are developed using a reputable Wisconsin study. It is recommended that future evaluation be conducted in Illinois to generate a more locally appropriate characterization.

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

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

Definition of Efficient Equipment

N/A

Definition of Baseline Equipment

This measure assumes that the existing unit being maintained is either a residential central air conditioning unit or an air source heat pump that has not been serviced for at least 3 years.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 2 years[364].

Deemed Measure Cost

If the implementation mechanism involves delivering and paying for the tune up service, the actual cost should be used. If however the customer is provided a rebate and the program relies on private contractors performing the work, the measure cost should be assumed to be $175[365].

Loadshape

Loadshape R08 - Residential Cooling

Coincidence Factor

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

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

= 68%[366]

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

= 72%%[367]

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[364] Based on VEIC professional judgment.

[365] Based on personal communication with HVAC efficiency program consultant Buck Taylor or Roltay Inc., 6/21/10, who estimated the cost of tune up at $125 to $225, depending on the market and the implementation details.

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

[367] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

= 46.6%[368]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh_{Central\ AC}$ = (FLHcool * Capacity_cooling* (1/$SEER_{CAC}$))/1000 * MFe

$\Delta kWh_{Air\ Source\ Heat\ Pump}$ = ((FLHcool * Capacity_cooling * (1/$SEER_{ASHP}$))/1000 * MFe) + (FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$))/1000 * MFe)

Where:

FLHcool = Full load cooling hours

Dependent on location as below:[369]

Climate Zone (City based upon)	FLHcool Single Family	FLHcool Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820
Weighted Average[370]	629	564

Capacity_cooling = Cooling cpacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)

= Actual

$SEER_{CAC}$ = SEER Efficiency of existing central air conditioning unit receiving maintenence

= Actual. If unknown assume 10 SEER [371]

MFe = Maintenance energy savings factor

= 0.05[372]

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

= Actual. If unknown assume 10 SEER [373]

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

[369] Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

[371] Use actual SEER rating where it is possible to measure or reasonably estimate. Unknown default of 10 SEER is a VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006.

[372] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[373] Use actual SEER rating where it is possible to measure or reasonably estimate. Unknown default of 10 SEER is a VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006.

FLHheat = Full load heating hours

Dependent on location:[374]

Climate Zone (City based upon)	FLHheat
1 (Rockford)	2208
2 (Chicago)	2064
3 (Springfield)	1967
4 (Belleville)	1420
5 (Marion)	1445
Weighted Average[375]	1821

Capacity_heating = Heating cpacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)

= Actual

$HSPF_{ASHP}$ = Heating Season Performance Factor of existing air source heat pump unit receiving maintenence

= Actual. If unknown assume 6.8 HSPF [376]

For example, maintenance of a 3-ton, SEER 10 air conditioning unit in a single family house in Springfield:

ΔkWh_{CAC} = (730 * 36,000 * (1/10))/1000 * 0.05

= 131 kWh

For example, maintenance of a 3-ton, SEER 10, HSPF 6.8 air source heat pump unit in a single family house in Springfield:

ΔkWh_{ASHP} = ((730 * 36,000 * (1/10))/1000 * 0.05) + (1967 * 36,000 * (1/6.8))/1000 * 0.05)

= 652 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Capacity_cooling * (1/EER)/1000 * MFd * CF

Where:

EER = EER Efficiency of existing unit receiving maintenance in Btu/H/Watts

= Calculate using Actual SEER

$= - 0.02*SEER^2 + 1.12*SEER$ [377]

[374] Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the Energy Star Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider Energy Star estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from http://www.icc.illinois.gov/ags/consumereducation.aspx) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the Energy Star data (1994 hours) to scale down the Energy Star estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

[376] Use actual HSPF rating where it is possible to measure or reasonably estimate. Unknown default of 6.8 HSPF is a VEIC estimate based on minimum Federal Standard between 1992 and 2006.

[377] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy

MFd = Maintenance demand savings factor

= 0.02 [378]

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

= 68%[379]

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

= 72%%[380]

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

= 46.6%[381]

For example, maintenance of 3-ton, SEER 10 (equals EER 9.2) CAC unit:

ΔkW_{SSP} = 36,000 * 1/(9.2)/1000 * 0.02 * 0.68

= 0.0532 kW

ΔkW_{PJM} = 36,000 * 1/(9.2)/1000 * 0.02 * 0.466

= 0.0365 kW

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Conservatively not included.

MEASURE CODE: RS-HVC-TUNE-V03-160601

REVIEW DEADLINE: 1/1/2021

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

378 Based on June 2010 personal conversation with Scott Pigg, author of Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research" suggesting the average WI unit system draw of 2.8kW under peak conditions, and average peak savings of 50W.

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

380 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

5.3.11 Programmable Thermostats

DESCRIPTION

This measure characterizes the household energy savings from the installation of a new or reprogramming of an existing Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Because a literature review was not conclusive in providing a defensible source of prescriptive cooling savings from programmable thermostats, cooling savings from programmable thermostats are assumed to be zero for this version of the measure. It is not appropriate to assume a similar pattern of savings from setting a thermostat down during the heating season and up during the cooling season. Note that the EPA's EnergyStar program is developing a new specification for this project category, and if/when evaluation results demonstrate consistent cooling savings, subsequent versions of this measure will revisit this assumption[382]. 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.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control, with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention. This category of equipment is broad and rapidly advancing in regards to the capability, and usability of the controls and their sophistication in setpoint adjustment and information display, but for the purposes of this characterization, eligibility is perhaps most simply defined by what it isn't: a manual only temperature control.

For the thermostat reprogramming measure, the auditor consults with the homeowner to determine an appropriate set back schedule, reprograms the thermostat and educates the homeowner on its appropriate use.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature setpoint.

For the purpose of thermostat reprogramming, an existing programmable thermostat that an auditor determines is being used in override mode or otherwise effectively being operated like a manual thermostat.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a programmable thermostat is assumed to be 10 years[383] based upon equipment life only[384]. For the purposes of claiming savings for a new programmable thermostat, this is reduced by a 50% persistence factor to give final measures life of 5 years. For reprogramming, this is reduced further to give a measure life of 2 years.

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown (e.g. through a

[382] The EnergyStar program discontinued its support for this measure category effective 12/31/09, and is presently developing a new specification for 'Residential Climate Controls'.
[383] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007
[384] 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.

retail program) the capital cost for the new installation measure is assumed to be $30[385]. The cost for reprogramming is assumed to be $10 to account for the auditors time to reprogram and educate the homeowner.

LOADSHAPE

Loadshape R09 - Residential Electric Space Heat

COINCIDENCE FACTOR

N/A due to no savings attributable to cooling during the summer peak period.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh[386] = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + (ΔTherms * F_e * 29.3)

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	6.5%[387]

Elec_Heating_ Consumption

= Estimate of annual household heating consumption for electrically heated single-family homes[388]. If location and heating type is unknown, assume 15,678 kWh[389]

[385] Market prices vary significantly in this category, generally increasing with thermostat capability and sophistication. The basic functions required by this measure's eligibility criteria are available on units readily available in the market for the listed price.

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

[387] Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat (consistent with Potential Study results from the state). Average value of 13% electric space heating from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[388] Values in table are based on converting an average household heating load (834 therms) for Chicago based on 'Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013 to an electric heat load (divide by 0.03413) 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 'Household Heating Load Summary Calculations_11062013.xls'). Finally these values were adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[389] Assumption that 1/2 of electrically heated homes have electric resistance and 1/2 have Heat Pump, based on 2010 Residential Energy Consumption Survey for Illinois.

Climate Zone (City based upon)	Electric Resistance Elec_Heating_ Consumption (kWh)	Electric Heat Pump Elec_Heating_ Consumption (kWh)
1 (Rockford)	21,741	12,789
2 (Chicago)	20,771	12,218
3 (Springfield)	17,789	10,464
4 (Belleville)	13,722	8,072
5 (Marion)	13,966	8,215
Average	19,743	11,613

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

= 6.2%[390]

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

Household Type	HF
Single-Family	100%
Multi-Family	65%[391]
Actual	Custom[392]

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%[393]

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%[394]

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

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

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

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

[394] 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

29.3 = kWh per therm

For example, a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield:

ΔkWH = 1 * 17,789 * 0.062 * 100% * 100% + (0 * 0.0314 * 29.3)

= 1,103 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A due to no savings from cooling during the summer peak period.

NATURAL GAS ENERGY SAVINGS

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

Where:

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

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	93.5%[395]

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below[396].

Climate Zone (City based upon)	Gas_Heating_ Consumption (therms)
1 (Rockford)	1,052
2 (Chicago)	1,005
3 (Springfield)	861
4 (Belleville)	664
5 (Marion)	676
Average	955

“Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.

395 Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat. Data from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

396 Values are based on adjusting the average household heating load (834 therms) for Chicago based on ‘Table E-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1, Research Report: Furnace Metering Study’, divided by standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24*0.92) + (0.76*0.8) = 0.83) to give 1005 therms. This Chicago value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

For example, a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

ΔTherms = 1.0 * 1005 * 0.062 * 100% * 100%

= 62.3 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-PROG-V04-180101

REVIEW DEADLINE: 1/1/2021

5.3.12 Ductless Heat Pumps

Description

This measure is designed to calculate electric savings for the installation of a ductless mini-split heat pump (DMSHP). DMSHPs save energy in heating mode because they provide heat more efficiently than electric resistance heat and central ASHP systems. Additionally, DMSHPs use less fan energy to move heat and don't incur heat loss through a duct distribution system.

For cooling, the proposed savings calculations are aligned with those of typical replacement systems. DMSHPs save energy in cooling mode because they provide cooling capacity more efficiently than other types of unitary cooling equipment. A DMSHP installed in a home with a central ASHP system will save energy by offsetting some of the cooling energy of the ASHP. In order for this measure to apply, the control strategy for the heat pump is assumed to be chosen to maximize savings per installer recommendation.[397]

This measure characterizes the following scenarios:

d) New Construction:
   a. The installation of a new DMSHP meeting efficiency standards required by the program in a new home.
   b. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

e) Time of Sale:
   a. The planned installation of a new DMSHP meeting efficiency standards required by the program to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   b. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.

f) Early Replacement/Retrofit:
   a. The early removal or displacement of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new DMSHP.
   b. Note the baseline in this case is the existing equipment being replaced/displaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   c. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced/displaced, or
      - The existing unit requires minor repairs, defined as costing less than[398]:

Existing System	Maximum repair cost
Air Source Heat Pump	$276 per ton
Central Air Conditioner	$190 per ton

[397] 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.

[398] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement.

Existing System	Maximum repair cost
Boiler	$709
Furnace	$528
Ground Source Heat Pump	<$249 per ton

- All other conditions will be considered Time of Sale.

d. The Baseline efficiency of the existing unit replaced:

- If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the "New Baseline" column below:

Existing System	Maximum efficiency for Actual	New Baseline[399]
Air Source Heat Pump	10 SEER	14 SEER
Central Air Conditioner	10 SEER	13 SEER
Boiler	75% AFUE	82% AFUE
Furnace	75% AFUE	80% AFUE
Ground Source Heat Pump	10 SEER	13 SEER

- If the efficiency of the existing unit is unknown, use assumptions in variable list below (SEER, HSPF or AFUE exist).
- If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8[400] EER.

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER.

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit, meeting the baselines provided below.

Unit Type	Efficiency Standard
ASHP	14 SEER, 11.8 EER, 8.2 HSPF

[399] Based on relevant Federal Standards.

[400] 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.

Unit Type	Efficiency Standard
Gas Furnace	80% AFUE
Gas Boiler	82% AFUE
Central AC	13 SEER, 11 EER

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating and cooling equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change). Note that in order to claim cooling savings, there must be an existing air conditioning system.

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 18 years[401].

For early replacement, the remaining life of existing equipment is assumed to be 6 years[402].

Deemed Measure Cost

New Construction and Time of Sale: The actual installed cost of the DMSHP should be used (defaults are provided below), minus the assumed installation cost of the baseline equipment ($1,381 per ton for ASHP[403] or $2,011 for a new baseline 80% AFUE furnace or $3,543 for a new 82% AFUE boiler[404] and $952 per ton[405] for new baseline Central AC replacement).

Unit Size	Full Install Cost[406]
1-Ton	$3,000
1.5-Ton	$3750
2-Ton	$4,500
2.5 – Ton	$5,313
3-Ton	$6,188

Early Replacement/retrofit (replacing existing equipment): The full installation cost of the DMSHP should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and $1,047 per ton for new baseline Central AC replacement[407]. This future cost should be discounted to present value using the nominal societal discount rate.

Where the DMSHP is a supplemental HVAC system, the full installation cost of the DMSHP should be used (default

[401] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007
[402] Assumed to be one third of effective useful life
[403] Based on data provided on Home Advisor website, providing national average ASHP cost based on 2465 cost submittals. http://www.homeadvisor.com/cost/heating-and-cooling/install-a-heat-pump/
[404] Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf). Where efficiency ratings are not provided, the values are interpolated from those that are.
[405] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls).

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

provided above) without a deferred replacement cost.

LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling	(if replacing gas heat and central AC)408
Loadshape R09 - Residential Electric Space Heat	(if replacing electric heat with no cooling)
Loadshape R10 - Residential Electric Heating and Cooling	(if replacing ASHP)

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

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in four different ways below. The first two relate to the use of DMSHP to supplement existing cooling or provide limited zonal cooling, the second two relate to use of the DMSHP to provide whole house cooling. In each pair, the first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on metering data for 40 DMSHPs in Ameren Illinois service territory[409].

For supplemental or limited zonal cooling:

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

= 43.1%%[410]

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

= 28.0%[411]

For whole house cooling:

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

= 72%%[412]

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

= 46.6%[413]

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

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

[410] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

[412] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'. http://www.icc.illinois.gov/downloads/public/edocket/368522.pdf

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

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

New Construction and Time of Sale (non-fuel switch only):

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Base} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

Early replacement (non-fuel switch only)[414]:

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

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Exist} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Exist} - 1/SEER_{ee})) / 1000]$

ΔkWH for remaining measure life (next 12 years):

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Base} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

Early replacement - fuel switch only :

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

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

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Exist} - 1/SEER_{ee})) / 1000]$

ΔkWh for remaining measure life (next 12 years):

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

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

= [(Capacity$_{heat}$ * EFLH$_{heat}$ * (1/HSPF$_{ASHP}$ - 1/HSPF$_{ee}$)) / 1000] + [(Capacity$_{cool}$* EFLH$_{cool}$ * (1/SEER$_{Base}$ - 1/SEER$_{ee}$)) / 1000]

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

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

= Actual

EFLH$_{heat}$ = Equivalent Full Load Hours for heating. Depends on location. See table below

Climate Zone (City based upon)	EFLH$_{heat}$[415]
1 (Rockford)	1,520
2 (Chicago)	1,421
3 (Springfield)	1,347
4 (Belleville)	977
5 (Marion)	994
Weighted Average	1,406

HSPF$_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

Existing Heating System	HSPF_base
Air Source Heat Pump	8.2
Electric Resistance	3.41[416]

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

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If unknown assume default:

Existing Equipment Type	HSPF$_{exist}$
Electric resistance heating	3.412[417]
Air Source Heat Pump	5.44[418]

HSPF$_{ASHP}$ =Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)

=8.2 [419]

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

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

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

418 This is from the ASHP measure which estimated HSPF 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.

419 Minimum Federal Standard as of 1/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

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

= Actual installed

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr[420].

= Actual installed

SEERbase = SEER Efficiency of new replacement baseline unit

Existing Cooling System	SEERbase
Air Source Heat Pump	14[421]
Central AC	13[422]
No central cooling	13[423]

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

= Actual installed[424]

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

= Use actual value. If unknown, see table below

Existing Cooling System	SEER_exist[425]
Air Source Heat Pump	9.12
Central AC	8.60
Room AC	8.0[426]
No existing cooling[427]	Make '1/SEER_exist' = 0

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. Depends on location. See table below[428].

Climate Zone (City based upon)	$EFLH_{cool}$
1 (Rockford)	323
2 (Chicago)	308
3 (Springfield)	468
4 (Belleville)	629
5 (Marion)	549

420 1 Ton = 12 kBtu/hr

421 Minimum Federal Standard as of 1/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

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

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

424 Note that if only an EER rating is available, use the following conversion equation; EER_base = (-0.02 * SEER_base²) + (1.12 * SEER). From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

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

426 Estimated by converting the EER assumption using the conversion equation; EER_base = (-0.02 * SEER_base²) + (1.12 * SEER). From Wassmer, M. (2003). 'A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations', Masters Thesis, University of Colorado at Boulder.

427 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.

428 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. FLH values are based on metering of multi-family units, and in buildings that had received weatherization improvements. Additional evaluation is recommended to refine the EFLH assumptions for the general population.

Climate Zone (City based upon)	$EFLH_{cool}$
Weighted Average[429]	364

For example, installing a 1.5-ton (heating and cooling capacity) ductless heat pump unit rated at 8 HSPF and 14 SEER in a single-family home in Chicago to displace electric baseboard heat and replace a window air conditioner of unknown efficiency, savings are:

ΔkWh_{heat} = (18000 * 1421 * (1/3.412 – 1/8))/1000 = 4,299 kWh

ΔkWh_{cool} = (18000 * 308 *(1/8.0 – 1/14)) /1000 = 297 kWh

ΔkWh = 4,299 + 297 = 4,596 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

New Construction and Time of Sale:

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

Early replacement:

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

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

ΔkW for remaining measure life (next 12 years):

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

Where:

EERbase = EER Efficiency of new replacement unit

Existing Cooling System	EER_base
Air Source Heat Pump	11.8[430]
Central AC	11 [431]
No central cooling	11[432]

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:

$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$ [433]

If SEER rating unavailable use:

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

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

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

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

433 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	EER_exist
Air Source Heat Pump	8.55[434]
Central AC	8.15[435]
Room AC	7.7[436]
No existing cooling[437]	Make '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: [438]

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

For supplemental or limited zonal cooling:

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

= 43.1%[439]

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

= 28.0%[440]

For whole house cooling:

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

= 72%[441]

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

= 46.6%[442]

NATURAL GAS SAVINGS

New Construction and Time of Sale with baseline gas heat:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms = [Heating Savings]

= [Replaced gas consumption – therm equivalent of DMSHP source kWh]

$= [(1 - ElecHeat) * ((Gas\_Heating\_Load/AFUEbase) - (kWhtoTherm * Capacity_{heat} *$

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

435 Ibid.

436 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."

437 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.

438 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.

439 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

441 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'. http://www.icc.illinois.gov/downloads/public/edocket/368522.pdf

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

$EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below, (electric savings is provided in Electric Energy Savings section):

ΔTherms = [Heating Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

Early replacement for homes with existing gas heat:

If measure is supported by gas utility only, gas utility claim savings calculated below:

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

= [Heating Savings]

= [Replaced gas consumption – therm equivalent of DMSHP source kWh]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

ΔTherms for remaining measure life (next 12 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below:

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

ΔTherms = [Heating Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

ΔTherms for remaining measure life (next 12 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

Gas_Heating_Load

= Estimate of annual household heating load [443] for gas furnace heated single-family homes. If location is unknown, assume the average below.

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[444].

[443] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE)

[444] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing

Climate Zone (City based upon)	Gas_Heating_Load if Furnace (therms) [445]	Gas_Heating_Load if Boiler (therms) [446]
1 (Rockford)	873	1275
2 (Chicago)	834	1218
3 (Springfield)	714	1043
4 (Belleville)	551	805
5 (Marion)	561	819
Average	793	1158

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating

= 80% if furnace and 82% if boiler.

AFUEexist = Existing Annual Fuel Utilization Efficiency Rating

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

If unknown, assume 64.4% if furnace and 61.6% [447] if boiler.

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

= 90%[448] if furnace and 82% if boiler.

kWhtoTherm = Converts source kWh to Therms

= H_{grid} / 100000

H_{grid} = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[449]. Also include any line losses.

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loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.

[445] Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[446] Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

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

[448] Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced.

[449] These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct. Refer to the latest EPA eGRID data. Current values, based on eGrid 2014 are:

- Non-Baseload RFC West: 9,346 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,157 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,931 Btu/kWh * (1 + Line Losses)

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

All other variables provided above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch DMSHP projects per Section 16-111.5B, changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[450]]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase)]

ΔkWh = - [DMSHP heating consumption] + [Cooling savings[451]]

= - [($Capacity_{heat}$ * $EFLH_{heat}$ * 1/HSPFee)/1000] + [($Capacity_{cool}$* $EFLH_{cool}$ * (1/$SEER_{Base}$- 1/$SEER_{ee}$)) / 1000]

MEASURE CODE: RS-HVC-DHP-V05-180101

REVIEW DEADLINE: 1/1/2020

- All Fossil Average SERC Midwest: 10,209 Btu/kWh * (1 + Line Losses)

[450] Note AFUEbase in the algorithm should be replaced with AFUEexist for early replacement measures.

[451] Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures.

5.3.13 Residential Furnace Tune-Up

Description

This measure is for a natural gas Residential furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

Two savings algorithms are provided for tune-up programs: through the HVAC SAVE program and for other tune-up programs, the difference being how relative efficiencies are measured.

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

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

Definition of Efficient Equipment

To qualify for this measure an approved technician must complete the tune-up requirements[452] listed below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer’s recommendations
- Where applicable Lubricate motor and inspect and replace fan belt if required
- Inspect for gas leaks
- Clean burner per manufacturer’s recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer’s recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring and controls for proper connections and performance
- Check air filter and clean or replace per manufacturer’s
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Check thermostat operation is per manufacturer’s recommendations(if adjustments made, refer to ‘Residential Programmable Thermostat’ measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

Verified Quality Maintenance:

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and BTU measurement to ensure that existing equipment is operating according to manufacturers’ published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Maintenance identifies sub-optimal performance and prescribes a solution during furnace tune ups.

The HVAC SAVE program has its own certifications and requirements. In addition to the maintenance described above, the following are key activities that are provided through an HVAC SAVE Verified Quality Maintenance visit[453]:

- Measure pressure drops at return, filter, coil and supply.
- Determine equipment air flow using OEM blower data or measuring.
- Measure temperature rise across heat exchanger.

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[452] American Standard Maintenance for Indoor Units: http://www.americanstandardair.com/owner-support/maintenance.html

[453] As provided in ANSI approved ACCA 4 specification for Quality Maintenance

- Determine on-rate for a furnace by clocking the gas meter.
- Record outdoor temperature & elevation, and complete test-in.
- Clean evaporator coil to OEM pressure drop specification.
- Clean/replace/modify air filter to OEM pressure drop specification.
- Reset air flow based on up design parameter and updated pressure conditions.
- Adjust/modify gas pressure and venting to OEM specifications.
- Complete final test-out, compare before and after

DEFINITION OF BASELINE EQUIPMENT

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

HVAC SAVE tune-ups are a one-time measure and cannot be performed more than once on the same piece of equipment.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the tune up is 2 years.[454]

An HVAC SAVE tune-up lasts the remaining life of the equipment because they come from adjustments to fans and ducts that remain effective through normal operation of the equipment. Assume 10 years.

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune up.

DEEMED O&M COST ADJUSTMENTS

There are no expected O&M savings associated with this measure.

LOADSHAPE

Loadshape R09 - Residential Electric Space Heat

COINCIDENCE FACTOR

N/A

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta Therms * F_e * 29.3$$

Where:

ΔTherms = as calculated below

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

= 3.14%[455]

[454] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.

[455] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

1. Verified Quality Maintenance:

$$\Delta Therms = (Gas\_Furnace\_Heating\_Load * HF * (1 /(AFUE * (1 - Derating_{pre})) - 1/(AFUE * (1 - Derating_{post}))$$

Where:

Gas_Furnace_Heating_Load = Estimate of annual household heating load[456] for gas furnace heated single-family homes. If location is unknown, assume the average below[457].

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[458].

Climate Zone (City based upon)	Gas_Furnace_Heating_Load (therms)
1 (Rockford)	873
2 (Chicago)	834
3 (Springfield)	714
4 (Belleville)	551
5 (Marion)	561
Average	793

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

Household Type	HF
Single-Family	100%
Multi-Family	65%[459]
Actual	Custom[460]

AFUE = Furnace Annual Fuel Utilization Efficiency Rating

= Actual

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.

[456] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE)

[457] Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[458] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home.

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

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

$Derating_{pre}$ = Furnace AFUE Derating before HVAC SAVE tune-up

= 6.4%[461]

$Derating_{post}$ = Furnace AFUE Derating after HVAC SAVE tune-up

= 0%

2. Other Tune-Up Programs:

ΔTherms =(Gas_Furnace_Heating_Load *HF * (1/ Effbefore – 1/ (Effbefore + Ei)))

Where:

Gas_Furnace_Heating_Load = Estimate of annual household heating load[462] for gas furnace heated single-family homes. If location is unknown, assume the average below[463].

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[464].

Climate Zone (City based upon)	Gas_Furnace_Heating_Load (therms)
1 (Rockford)	873
2 (Chicago)	834
3 (Springfield)	714
4 (Belleville)	551
5 (Marion)	561
Average	793

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

Household Type	HF
Single-Family	100%
Multi-Family	65%[465]
Actual	Custom[466]

Effbefore = Efficiency of the furnace before the tune-up

= Actual

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

[461] Based on findings from Building America, US Department of Energy, Brand, Yee and Baker "Improving Gas Furnace Performance: A Field and Laboratory Study at End of Life", February 2015.

[462] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE)

[463] Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[464] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home.

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

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

EI = Efficiency Improvement of the furnace tune-up measure

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-FTUN-V03-180101

REVIEW DEADLINE: 1/1/2021

5.3.14 Boiler Reset Controls

DESCRIPTION

This measure relates to improving system efficiency by adding controls to residential heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. The water can be run a little cooler during fall and spring, and a little hotter during the coldest parts of the winter. A boiler reset control has two temperature sensors - one outside the house and one in the boiler water. As the outdoor temperature goes up and down, the control adjusts the water temperature setting to the lowest setting that is meeting the house heating demand. There are also limits in the controls to keep a boiler from operating outside of its safe performance range.[467]

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

DEFINITION OF EFFICIENT EQUIPMENT

Natural gas single family residential customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse fashion with outdoor air temperature. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer's recommended minimum return temperature. This boiler reset measure is limited to existing condensing boilers serving a single family residence. Boiler reset controls for non-condensing boilers in single family residences should be implemented as a custom measure, and the cost-effectiveness should be confirmed.

DEFINITION OF BASELINE EQUIPMENT

Existing condensing boiler in a single family residential setting without boiler reset controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 20 years[468]

DEEMED MEASURE COST

The cost of this measure is $612[469]

LOADSHAPE

NA

COINCIDENCE FACTOR

N/A

[467] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. Boiler Reset Control, accessed at http://naturalgasefficiency.org/residential/Boiler_Reset_Control.htm
[468] CLEAResultreferences the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.
[469] Nexant. Questar DSM Market Characterization Report. August 9, 2006.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

NA

Natural Gas Savings

ΔTherms = Gas_Boiler_Load * (1/AFUE) * Savings Factor

Where:

Gas_Boiler_Load[470]

= Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below[471].

= or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[472].

Climate Zone (City based upon)	Gas_Boiler Load (therms)
1 (Rockford)	1275
2 (Chicago)	1218
3 (Springfield)	1043
4 (Belleville)	805
5 (Marion)	819
Average	1158

AFUE = Existing Condensing Boiler Annual Fuel Utilization Efficiency Rating

= Actual.

SF = Savings Factor, 5%[473]

[470] Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Heating load is used to describe the household heating need, which is equal to (gas heating consumption * AFUE)

[471] Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[472] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations should be completed by contractors during the selection process and may be readily available for program data purposes.

[473] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. Boiler Reset Control, accessed at http://naturalgasefficiency.org/residential/Boiler_Reset_Control.htm

EXAMPLE

For example, boiler reset controls on a 92.5 AFUE boiler at a household in Rockford, IL

ΔTherms = 1275 * (1/0.925) * 0.05

= 69 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-BREC-V01-150601

REVIEW DEADLINE: 1/1/2021

5.3.15 ENERGY STAR Ceiling Fan

Description

A ceiling fan/light unit meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard. ENERGY STAR qualified ceiling fan/light combination units are over 60% more efficient than conventional fan/light units, and use improved motors and blade designs[474].

Due to the savings from this measure being derived from more efficient ventilation and more efficient lighting, and the loadshape and measure life for each component being very different, the savings are split in to the component parts and should be claimed together. Lighting savings should be estimated utilizing the 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

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

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

Definition of Efficient Equipment

The efficient equipment is defined as an ENERGY STAR certified ceiling fan with integral CFL bulbs.

Definition of Baseline Equipment

The baseline equipment is assumed to be a standard fan with efficient incandescent or halogen light bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012 followed by restrictions on 75W in 2013 and 60W and 40W in 2014, due to the Energy Independence and Security Act of 2007 (EISA). Finally, a provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) for the lighting portion of the savings should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

Deemed Lifetime of Efficient Equipment

The fan savings measure life is assumed to be 10 years.[2]

The lighting savings measure life is assumed to be 3 years for lighting savings for units installed in 2018, and then for every subsequent year should be reduced by one year[475] (see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure).

Deemed Measure Cost

Incremental cost of unit is $46.[476]

Loadshape

R06 - Residential Indoor Lighting

R11 - Residential Ventilation

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[474] http://www.energystar.gov/products/certified-products/detail/ceiling-fans

[475] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

[476] ENERGY STAR Ceiling Fan Savings Calculator
http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?8178-e52c

Coincidence Factor

The summer peak coincidence factor for the ventilation savings is assumed to be 30%.[477]

For lighting savings, see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

Algorithm

Calculation of Savings

Electric Energy Savings

$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{Light}$

$\Delta kWh_{fan} = [Days * FanHours * ((\%Low_{base} * WattsLow_{base}) + (\%Med_{base} * WattsMed_{base}) + (\%High_{base} * WattsHigh_{base}))/1000\ ] - [Days * FanHours * ((\%Low_{ES} * WattsLow_{ES}) + (\%Med_{ES} * WattsMed_{ES}) + (\%High_{ES} * WattsHigh_{ES}))/1000]$

ΔkWh_{light} = see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

Where[478]:

Days = Days used per year

= Actual. If unknown use 365.25 days/year

FanHours = Daily Fan “On Hours”

= Actual. If unknown use 3 hours

$\%Low_{base}$ = Percent of time spent at Low speed of baseline

= 40%

$WattsLow_{base}$ = Fan wattage at Low speed of baseline

= Actual. If unknown use 15 watts

$\%Med_{base}$ = Percent of time spent at Medium speed of baseline

= 40%

$WattsMed_{base}$ = Fan wattage at Medium speed of baseline

= Actual. If unknown use 34 watts

$\%High_{base}$ = Percent of time spent at High speed of baseline

= 20%

$WattsHigh_{base}$ = Fan wattage at High speed of baseline

= Actual. If unknown use 67 watts

%LowES = Percent of time spent at Low speed of ENERGY STAR

[477] Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

[478] All fan default assumptions are based upon assumptions provided in the ENERGY STAR Ceiling Fan Savings Calculator; http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?8178-e52c

= 40%

$WattsLow_{ES}$ = Fan wattage at Low speed of ENERGY STAR

= Actual. If unknown use 6 watts

$\%Med_{ES}$ = Percent of time spent at Medium speed of ENERGY STAR

= 40%

$WattsMed_{ES}$ = Fan wattage at Medium speed of ENERGY STAR

= Actual. If unknown use 23 watts

$\%High_{ES}$ = Percent of time spent at High speed of ENERGY STAR

= 20%

$WattsHigh_{ES}$ = Fan wattage at High speed of ENERGY STAR

= Actual. If unknown use 56 watts

For ease of reference, the fan assumptions are provided below in table form:

	Low Speed	Medium Speed	High Speed
Percent of Time at Given Speed	40%	40%	20%
Conventional Unit Wattage	15	34	67
ENERGY STAR Unit Wattage	6	23	56
ΔW	9	11	11

If the lighting WattsBase and WattsEE is unknown, assume the following

WattsBase = 3 x 43 = 129 W

WattsEE = 1 x 42 = 42 W

EXAMPLE

For example, a ceiling fan with three 43W bulb light fixtures, replaced with an ES ceiling fan with one 42W bulb light fixture, the savings are:

ΔkWh_{fan} = [365.25*3*((0.4*15)+(0.4*34)+(0.2*67))/1000] – [365.25*3*((0.4*6)+(0.4*23)+(0.2*56))/1000]

= 36.2 – 25.0 = 11.2 kWh

ΔkWh_{light} =((129 – 42)/1000) *759 * 1.06

= 70.0 kWh

ΔkWh = 11.2 + 70

=81.2 kWh

Using the default assumptions provided above, the deemed savings is 81.2 kWh.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kW_{Fan} + \Delta kW_{light}$

$\Delta kW_{Fan} = ((WattsHigh_{base} - WattsHigh_{ES})/1000) * CF_{fan}$

ΔkW_{Light} = see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

Where:

CF_{fan} = Summer Peak coincidence factor for ventilation savings

= 30%[479]

CF_{light} = Summer Peak coincidence factor for lighting savings

= 7.1%[480]

EXAMPLE

For example a ceiling fan with three 43W bulb light fixtures, replaced with an ES ceiling fan with one 42W bulb light fixture, the savings are:

ΔkW_{fan} = ((67-56)/1000) * 0.3

=0.0033 kW

ΔkW_{light} =((129 – 42)/1000) * 1.11 * 0.071

= 0.0068 kW

ΔkW = 0.0033 + 0.0068

= 0.010 kW

Using the default assumptions provided above, the deemed savings is 0.010kW.

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure for bulb replacement costs.

MEASURE CODE: RS-HVC-CFAN-V02-180101

REVIEW DEADLINE: 1/1/2022

[479] Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

[480] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

5.3.16 Advanced Thermostats

DESCRIPTION

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating and cooling consumption through a configurable schedule of temperature setpoints (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[481] 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.[482] 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[483] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

DEFINITION OF BASELINE EQUIPMENT

The baseline is either the actual type (manual or programmable) if it is known,[484] or an assumed mix of these two

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[481] 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.

[482] 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'.

[483] 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.

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

types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 44% programmable and 56% manual thermostats may be assumed[485].

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[486] based upon equipment life only.[487]

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[488], or other program types actual costs are still preferable[489] but if unknown then the average incremental cost for the new installation measure is assumed to be $175[490].

LOADSHAPE

ΔkWh → Loadshape R10 - Residential Electric Heating and Cooling
$\Delta kWh_{heating}$ → Loadshape R09 - Residential Electric Space Heat
$\Delta kWh_{cooling}$ → Loadshape R08 - Residential Cooling

COINCIDENCE FACTOR

In the absence of conclusive results from empirical studies on peak savings, the TAC agreed to a temporary assumption of 50% of the cooling coincidence factor, acknowledging that while the savings from the advanced Thermostat will track with the cooling load, the impact during peak periods may be lower. This is an assumption that could use future evaluation to improve these estimates.

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 34%[491]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[492]

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485 Based on Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013.

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

487 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.

488 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.

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

490 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.

491 Assumes 50% of the cooling coincidence factor (based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory).

492 Assumes 50% of the cooling coincidence factor (based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh[493] = $\Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating}$ = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + (ΔTherms * F_e * 29.3)

ΔkWh_{cool} = %AC * ((FLH * Btu/hr * 1/SEER)/1000) * Cooling_Reduction * Eff_ISR

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	6.5%[494]

Elec_Heating_Consumption

= Estimate of annual household heating consumption for electrically heated single-family homes[495]. If location and heating type is unknown, assume 15,678 kWh[496]

Climate Zone (City based upon)	Electric Resistance Elec_Heating_ Consumption (kWh)	Electric Heat Pump Elec_Heating_ Consumption (kWh)
1 (Rockford)	21,741	12,789
2 (Chicago)	20,771	12,218
3 (Springfield)	17,789	10,464
4 (Belleville)	13,722	8,072
5 (Marion)	13,966	8,215
Average	19,743	11,613

Heating_Reduction = Assumed percentage reduction in total household heating energy

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493 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.

494 Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat (consistent with Potential Study results from the state). Average value of 13% electric space heating from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

495 Values in table are based on converting an average household heating load (834 therms) for Chicago based on 'Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013 to an electric heat load (divide by 0.03413) 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 'Household Heating Load Summary Calculations_11062013.xls'). Finally these values were adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

496 Assumption that 1/2 of electrically heated homes have electric resistance and 1/2 have Heat Pump, based on 2010 Residential Energy Consumption Survey for Illinois.

consumption due to advanced thermostat

Existing Thermostat Type	Heating_Reduction[497]
Manual	8.8%
Programmable	5.6%
Unknown (Blended)	7.4%

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

Household Type	HF
Single-Family	100%
Multi-Family	65%[498]
Actual	Custom[499]

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication. Note that retrospective adjustments should be made during evaluation verification activities through the use of a realization rate if the program design does not ensure that each advanced thermostat is actually installed and/or if the evaluation determines that the advanced thermostat is not actually installed in the Program Administrator's service territory.

Program Delivery	Eff_ISR
Direct Install	100%
Other	100%[500]

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%[501]

29.3 = kWh per therm

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

[497] These values represent adjusted baseline savings values (8.8% for manual, and 5.6% for programmable thermostats) as presented in Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'). These values are used as the basis for the weighted average savings value when the type of existing thermostat is not known. Using the default assumption of 56% manual and 44% programmable as described in the baseline definition section above the 7.4% savings value is equal to the sum of proportional savings for manual and programmable thermostats: 8.8% * 0.56 + 5.6% * 0.44. Further evaluation and regular review of this key assumption is encouraged.

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

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

[500] 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.

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

Thermostat control of air conditioning?	%AC
Yes	100%
No	0%
Unknown	66%[502]
Unknown Multi-Family	46% [503]
Unknown Single Family	87%[504]

FLH = Estimate of annual household full load cooling hours for air conditioning equipment based on location and home type. If location and cooling type are unknown, assume the weighted average.

Climate zone (city based upon)	FLH (single family) [505]	FLH (general multifamily) [506]	FLH_cooling (weatherized multi family) [507]
1 (Rockford)	512	467	243
2 (Chicago)	570	506	263
3 (Springfield)	730	663	345
4 (Belleville)	1035	940	489
5 (Marion)	903	820	426
Weighted average[508]	629	564	293

Btu/hr = Size of AC unit[509]. (Note: One refrigeration ton is equal to 12,000 Btu/hr.)

Program Delivery	Btu/hr
Direct Install (Single Family known, or MF)	Actual
Unknown (Single family home only)	33,600

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.

Cooling System	SEER[510]
Air Source Heat Pump	9.12
Central AC	8.60

1/1000 = kBtu per Btu

[502] 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey;

[503] Based on Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, April 2013.

[504] Ibid.

[505] Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[506] Ibid.

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

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

[509] 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.

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

Cooling_Reduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat[511]:

= 8.0%[512]

For example, an advanced thermostat replacing a programmable thermostat directly installed in an electric heat pump heated, single-family home in Springfield with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

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

$= 1 * 10{,}464 * 5.6\% * 100\% * 100\% + (0 * 0.0314 * 29.3) + 100\% * ((730 * 33{,}600 * (1/9.12))/1000) * 8\% * 100\%$

= 586kWh + 215 kWh

= 801 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \%AC * (Cooling\_Reduction * Btu/hr * (1/EER))/1000 * EFF\_ISR * CF$

Where:

EER = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)

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

$EER = (-0.02 * SEER\_exist^2) + (1.12 * SEER\_exist)$ [513]

If SEER or EER rating unavailable use:

Cooling System	EER[514]
Air Source Heat Pump	8.55
Central AC	8.15

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 34%[515]

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

[511] The Technical Advisory Committee is currently collaborating on a plan for an upcoming evaluation that will relate to the exact population this measure represents, and results of that evaluation will be used to update this assumption when it is finalized.

[512] This assumption is based upon the review of many evaluations from other regions in the US (see Navigant workpaper "Illinois Statewide TRM Workpaper_RES_Smart Thermostats_2015 11 02.docx" and VEIC summary "Studies informing the Illinois TRM Savings Characterization for Advanced Thermostats.docx"). These sources, are from different regions, products, and program delivery designs, but collectively form a sound basis, and directional guidance for the existence and magnitude of cooling savings. Because cooling savings are more volatile than those for heating due to variables in control behaviors, population, and product factors, conservatism is warranted and 8% was considered a conservative estimate based upon the array of results from these studies available at the time this value was developed. Further evaluation and regular review of this key assumption is encouraged.

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

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

[515] Assumes 50% of the cooling coincidence factor (based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.)

= 23.3%[516]

Other variables as provided above

> For example, an advanced thermostat replacing a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:
>
> ΔkW_{SSP} = 100% * 8% * 33,600 * (1/8.15))/1000) * 100% * 34%
>
> = 0.11 kW
>
> ΔkW_{PJM} = 100% * 8% * 33,600 * (1/8.15))/1000) * 100% * 23.3%
>
> = 0.077 kW

NATURAL GAS ENERGY SAVINGS

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

Where:

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

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	93.5%[517]

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below[518].

Climate Zone (City based upon)	Gas_Heating_ Consumption (therms)
1 (Rockford)	1,052
2 (Chicago)	1,005
3 (Springfield)	861
4 (Belleville)	664

516 Assumes 50% of the cooling coincidence factor (based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.)

517 Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat. Data from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

518 Values are based on adjusting the average household heating consumption (849 therms) for Chicago based on 'Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor', calculating inferred heating load by dividing by average efficiency of new in program units in the study (94.4%) and then applying standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24*0.92) + (0.76*0.8) = 0.83). This Chicago value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

Climate Zone (City based upon)	Gas_Heating_ Consumption (therms)
5 (Marion)	676
Average	955

Other variables as provided above

For example, an advanced thermostat replacing a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

ΔTherms = 1.0 * 1005 * 5.6% * 100% * 100%

= 56.28 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ADTH-V02-180101

REVIEW DEADLINE: 1/1/2019

5.4 Hot Water End Use

5.4.1 Domestic Hot Water Pipe Insulation

DESCRIPTION

This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to 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 length therefore helps reduce standby losses. Default savings are provided per 3ft length and are appropriate up to 6ft of the hot water pipe and 3ft of the cold.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

The baseline is an un-insulated hot water pipe.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years[519].

DEEMED MEASURE COST

The measure cost including material and installation is assumed to be $3 per linear foot[520].

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

This measure assumes a flat loadshape since savings relate to reducing standby losses and as such the coincidence factor is 1.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For electric DHW systems:

$$\Delta kWh = ((1/Rexist - 1/Rnew) * (L * C) * \Delta T * 8{,}766) / \eta DHW / 3413$$

Where:

[519] 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

[520] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

Rexist = Pipe heat loss coefficient of uninsulated pipe (existing) [(hr-°F-ft)/Btu]

= 1.0[521]

Rnew = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft)/Btu]

= Actual (1.0 + R value of insulation)

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

= Actual

C = Circumference of pipe (ft) (Diameter (in) * π/12)

= Actual (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)

ΔT = Average temperature difference between supplied water and outside air temperature (°F)

= 60°F [522]

8,766 = Hours per year

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [523]

3412 = Conversion from Btu to kWh

For example, insulating 5 feet of 0.75" pipe with R-5 wrap:

ΔkWh = ((1/Rexist – 1/Rnew) * (L * C) * ΔT * 8,766) / ηDHW / 3412

= ((1/1– 1/(1+5) * (5 * 0.196) * 60 * 8766) / 0.98 /3412

= 128 kWh

If inputs above are not available the following default per 3ft R-5 length can be used for up to 6 ft length on the hot pipe and 3 ft on the cold pipe.

ΔkWh = ((1/Rexist – 1/Rnew) * (L * C) * ΔT * 8,766) / ηDHW / 3412

= ((1/1– 1/(1+5)) * (3 * 0.196) * 60 * 8766) / 0.98 /3412

= 77.1 kWh per 3ft length

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW **=** ΔkWh / 8766

Where:

ΔkWh = kWh savings from pipe wrap installation

8766 = Number of hours in a year (since savings are assumed to be constant over year).

[521] Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77.
[522] Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.
[523] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

For example, insulating 5 feet of 0.75” pipe with R-5 wrap:

$$\Delta kW = 128/8766$$
$$= 0.015 kW$$

If inputs above are not available the following default per 3ft R-4 length can be used for up to 6 ft length on the hot pipe and 3 ft on the cold pipe.

$$\Delta kW = 77.1/8766$$
$$= 0.0088\ kW$$

NATURAL GAS SAVINGS

For Natural Gas DHW systems:

$$\Delta Therm = ((1/Rexist – 1/Rnew) * (L * C) * \Delta T * 8,766) / \eta DHW /100,000$$

Where:

ηDHW = Recovery efficiency of gas hot water heater

= 0.78 [524]

Other variables as defined above

For example, insulating 5 feet of 0.75” pipe with R-5 wrap:

$$\Delta Therm = ((1/1– 1/(1+5)) * (5 * 0.196) * 60 * 8766) / 0.78 / 100,000$$
$$= 5.51\ therms$$

If inputs above are not available the following default per 3ft R-4 length can be used for up to 6ft length on the hot pipe and 3ft on the cold pipe.

$$\Delta Therm = ((1/Rexist – 1/Rnew) * (L * C) * \Delta T * 8,766) / \eta DHW / 100,000$$
$$= ((1/1– 1/(1+5)) * (3 * 0.196) * 60 * 8766) / 0.78 /100,000$$
$$= 3.30\ therms\ per\ 3ft\ length$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-PINS-V02-150601

REVIEW DEADLINE: 1/1/2019

[524] 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%

5.4.2 Gas Water Heater

DESCRIPTION

This measure characterizes:

a) Time of sale or new construction:
The purchase and installation of a new efficient gas-fired water heater, in place of a Federal Standard unit in a residential setting. Savings are provided for power-vented, condensing storage, and whole-house tankless units meeting specific EF criteria.

b) Early replacement:
The early removal of an existing functioning natural gas water heater from service, prior to its natural end of life, and replacement with a new high efficiency unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the efficient equipment must be a water heater rated with the following minimum efficiency ratings:

Water Heater Type	Minimum Energy Factor
Gas Storage	0.67
Condensing gas storage	0.80
Tankless whole-house unit	0.82

DEFINITION OF BASELINE EQUIPMENT

Time of Sale or New Construction: The baseline condition is assumed to be a standard gas storage water heater of the same capacity as the efficient unit, rated at the federal minimum. For 20 to 55 gallon tanks the Federal Standard is calculated as 0.675 – (0.0015 * storage size in gallons) and for tanks 55 - 100 gallon 0.8012 – (0.00078 * storage size in gallons)[525]. For a 40-gallon storage water heater this would be 0.615 EF.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.[526]

For early replacement: Remaining life of existing equipment is assumed to be 4 years[527].

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[525] Minimum Federal Standard as of 4/1/2015;
http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

[526] DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf Note: This source is used to support this category in aggregate. For all water heaters, life expectancy will depend on local variables such as water chemistry and homeowner maintenance. Some categories, including condensing storage and tankless water heaters do not yet have sufficient field data to support separate values. Preliminary data show lifetimes may exceed 20 years, though this has yet to be sufficiently demonstrated.

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

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[528].

Early Replacement: The full installed cost is provided in the table below. The assumed deferred cost (after 4 years) of replacing existing equipment with a new baseline unit is assumed to be $650[529]. This cost should be discounted to present value using the nominal discount rate.

Water heater Type	Incremental Cost	Full Install Cost
Gas Storage	$400	$1014
Condensing gas storage	$685	$1299
Tankless whole-house unit	$605	$1219

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = (1/\ EF_{BASE} - 1/EF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0\ )/100{,}000$$

Early replacement[530]:

ΔTherms for remaining life of existing unit (1st 4 years):

$$= (1/\ EF_{EXISTING} - 1/EF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0\ )/100{,}000$$

ΔTherms for remaining measure life (next 9 years):

[528] Source for cost info; DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf)

[529] The deemed install cost of a Gas Storage heater is based upon DCEO Efficient Living Program Data for a sample size of 157 gas water heaters, and applying inflation rate of 1.91%.

[530] 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).

$= (1/ EF_{BASE} - 1/EF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0)/100,000$

Where:

EF_Baseline = Energy Factor rating for baseline equipment

For <=55 gallons: 0.675 – (0.0015 * tank_size)

For > 55 gallons: 0.8012 – (0.00078 * tank size)

= If tank size unknown assume 40 gallons and EF_Baseline of 0.615

EF_Efficient = Energy Factor Rating for efficient equipment

= Actual. If Tankless whole-house multiply rated efficiency by 0.91[531]. If unknown assume values in look up in table below

Water Heater Type	EF_Efficient
Condensing Gas Storage	0.80
Gas Storage	0.67
Tankless whole-house	0.82 * 0.91 = 0.75

EF_Existing = Energy Factor rating for existing equipment

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

= if unknown assume 0.52 [532]

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[533]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[534]
Multi-Family - Deemed	2.1[535]
Custom	Actual Occupancy or Number of Bedrooms[536]

365.25 = Days per year, on average

---

[531] The disconnect between rated energy factor and in-situ energy consumption is markedly different for tankless units due to significantly higher contributions to overall household hot water usage from short draws. In tankless units the large burner and unit heat exchanger must fire and heat up for each draw. The additional energy losses incurred when the mass of the unit cools to the surrounding space in-between shorter draws was found to be 9% in a study prepared for Lawrence Berkeley National Laboratory by Davis Energy Group, 2006. "Field and Laboratory Testing of Tankless Gas Water Heater Performance" Due to the similarity (storage) between the other categories and the baseline, this derating factor is applied only to the tankless category.

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

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

[534] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[535] Navigant, ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012.

[536] 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.

$\gamma Water$ = Specific Weight of water

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= 125°F

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

= 54°F[537]

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

For example, a 40 gallon condensing gas storage water heater, with an energy factor of 0.80 in a single family house:

ΔTherms = (1/0.615 - 1/0.8) * (17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1) / 100,000

= 36.6 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-GWHT-V07-180101

REVIEW DEADLINE: 1/1/2021

[537] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

5.4.3 Heat Pump Water Heaters

Description

The installation of a heat pump domestic hot water heater in place of a standard electric water heater in a home. Savings are presented dependent on the heating system installed in the home due to the impact of the heat pump water heater on the heating loads.

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

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

Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a Heat Pump domestic water heater.

Definition of Baseline Equipment

The baseline condition is assumed to be a new electric water heater meeting federal minimum efficiency standards[538]:

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

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 13 years.[539]

Deemed Measure Cost

The incremental capital cost for this measure is $1,000, for a HPWH with an energy factor of 2.0. The full cost, applicable in a retrofit, is $1,575. For a HPWH with an energy factor of 2.35, these costs are $1,134 and $1,703 respectively.[540]

Loadshape

Loadshape R03 - Residential Electric DHW

Coincidence Factor

The summer Peak Coincidence Factor is assumed to be 12%.[541]

[538] Minimum Federal Standard as of 4/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

[539] DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Page 8-52 http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf

[540] DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14 http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf

[541] Calculated from Figure 8 "Combined six-unit summer weekday average electrical demand" in FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf as (average kW usage during peak period * hours in peak period) / [(annual kWh savings / FLH) * hours in peak period] = (0.1 kW * 5 hours) / [(2100 kWh (default assumptions) / 2533 hours) * 5 hours] = 0.12

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$\Delta kWh = (((1/EF_{BASE} - 1/EF_{EFFICIENT}) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) + kWh\_cooling - kWh\_heating$

Where:

EF_{BASE} = Energy Factor (efficiency) of standard electric water heater according to federal standards[542]:

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

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

= 0.945 for a 50 gallon tank, the most common size for HPWH

$EF_{EFFICIENT}$ = Energy Factor (efficiency) of Heat Pump water heater

= Actual

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[543]

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[544]
Multi-Family - Deemed	2.1[545]
Custom	Actual Occupancy or Number of Bedrooms[546]

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= 125°F

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

[542] Minimum Federal Standard as of 1/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

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

[544] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[545] Navigant, ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012.

[546] 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.

= 54°F[547]

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

3412 = Conversion from Btu to kWh

kWh_cooling[548] = Cooling savings from conversion of heat in home to water heat

$=(((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) -$

$((1/ EF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 27\%) / COP_{COOL}) * LM$

Where:

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location

= 0.0 for installation in an unconditioned space

27% = Portion of reduced waste heat that results in cooling savings[549]

COP_{COOL} = COP of central air conditioning

= Actual, if unknown, assume 3.08 (10.5 SEER / 3.412)

LM = Latent multiplier to account for latent cooling demand

= 1.33 [550]

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

$= (((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) -$

$((1/ EF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 49\%) / COP_{HEAT}) * (1 - \%NaturalGas)$

Where:

49% = Portion of reduced waste heat that results in increased heating load[551]

COP_{HEAT} = COP of electric heating system

= actual. If not available use[552]:

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[547] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

[548] This algorithm calculates the heat removed from the air by subtracting the HPWH electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the HP unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling and latent cooling demands.

[549] REMRate determined percentage (27%) of lighting savings that result in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

[550] A sensible heat ratio (SHR) of 0.75 corresponds to a latent multiplier of 4/3 or 1.33. SHR of 0.75 for typical split system from page 10 of "Controlling Indoor Humidity Using Variable-Speed Compressors and Blowers" by M. A. Andrade and C. W. Bullard, 1999: www.ideals.illinois.edu/bitstream/handle/2142/11894/TR151.pdf

[551] REMRate determined percentage (49%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

[552] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[553]	N/A	N/A	1.28

For example, a 2.0 EF heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning (SEER 10.5) in Belleville:

ΔkWh = [(1 / 0.945 – 1 / 2.0) * 17.6 * 2.56 * 365.25* 8.33 * (125 – 54)] / 3412 + 166.3 - 0

= 1759 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / Hours * CF

Where:

Hours = Full load hours of water heater

= 2533 [554]

CF = Summer Peak Coincidence Factor for measure

= 0.12 [555]

For example, a 2.0 COP heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning in Belleville:

kW = 1759 / 2533 * 0.12

= 0.083 kW

NATURAL GAS SAVINGS

ΔTherms = - ((((GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) – (((GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) / $EF_{EFFICIENT}$)) * LF * 49% * 0.03412) / ηHeat) * %NaturalGas

Where:

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

553 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

554 Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

555 Calculated from Figure 8 "Combined six-unit summer weekday average electrical demand" in FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf as (average kW usage during peak period * hours in peak period) / [(annual kWh savings / FLH) * hours in peak period] = (0.1 kW * 5 hours) / [(2100 kWh / 2533 hours) * 5 hours] = 0.12

heat.[556]

0.03412 = conversion factor (therms per kWh)

ηHeat = Efficiency of heating system

= Actual.[557] If not available use 70%.[558]

%NaturalGas = Factor dependent on heating fuel:

Heating System	%NaturalGas
Electric resistance or heat pump	0%
Natural Gas	100%
Unknown heating fuel[559]	87%

Other factors as defined above

For example, a 2.0 COP heat pump water heater in conditioned space, in a single family home with gas space heat (70% system efficiency):

ΔTherms = -((((17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1.0) / 3412) – (17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1.0 / 3412 / 2.0)) * 1 * 0.49 * 0.03412) / (0.7 * 1)

= - 34.1 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-HPWH-V06-180101

REVIEW DEADLINE: 1/1/2021

[556] This is the additional energy consumption required to replace the heat removed from the home during the heating season by the heat pump water heater. kWh_heating (electric resistance) is that additional heating energy for a home with electric resistance heat (COP 1.0). This formula converts the additional heating kWh for an electric resistance home to the MMBtu required in a Natural Gas heated home, applying the relative efficiencies.

[557] 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.

[558] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey: http://www.eia.gov/consumption/residential/data/2009/xls/HC6.9%20Space%20Heating%20in%20Midwest%20Region.xls))
In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[559] 2010 American Community Survey.

5.4.4 Low Flow Faucet Aerators

DESCRIPTION

This measure relates to the installation of a low flow faucet aerator in a household kitchen or bath faucet fixture.

This measure may be used for units provided through Efficiency 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 9 years.[560]

DEEMED MEASURE COST

For time of sale or new construction the incremental cost for this measure is $3[561] or program actual.

For faucet aerators provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $8[562] for Direct Install and $3 for Efficiency Kits.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 2.2%.[563]

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[560] Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. "http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf"

[561] 2011, Market research average of $3.

[562] Includes assess and install labor time of $5 (20min @ $15/hr)

[563] Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% *180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[564] (unless faucet type is unknown, then it is per household).

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

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%[565]

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[566] or custom based on metering studies[567] or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[568]

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

= 0.94[569] or custom based on metering studies[570] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[571]

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

565 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

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

567 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.

568 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

569 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.

570 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.

571 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.

L_base = Average baseline daily length faucet use per capita for faucet of interest in minutes

= if available custom based on metering studies, if not use:

Faucet Type	L_base (min/person/day)
Kitchen	4.5[572]
Bathroom	1.6[573]
If location unknown (total for household): Single-Family	9.0[574]
If location unknown (total for household): Multi-Family	6.9[575]

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[576]
Bathroom	1.6[577]
If location unknown (total for household): Single-Family	9.0[578]
If location unknown (total for household): Multi-Family	6.9[579]

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.56[580]
Multi-Family - Deemed	2.1[581]
Custom	Actual Occupancy or Number of Bedrooms[582]

www.seattle.gov/light/Conserve/Reports/paper_10.pdf

572 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.

573 Ibid.

574 One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

575 One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

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

577 Ibid.

578 One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

579 One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

580 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

581 Navigant, ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012.

582 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[583]
Kitchen	75%
Bath	90%
Unknown	79.5%

FPH = Faucets Per Household

0	FPH
Kitchen Faucets Per Home (KFPH)	1
Bathroom Faucets Per Home (BFPH): Single-Family	2.83[584]
Bathroom Faucets Per Home (BFPH): Multi-Family	1.5[585]
If location unknown (total for household): Single-Family	3.83
If location unknown (total for household): Multi-Family	2.5

EPG_electric = Energy per gallon of water used by faucet supplied by electric water heater

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

= (8.33 * 1.0 * (86 – 54.1)) / (0.98 * 3412)

= 0.0795 kWh/gal (Bath), 0.0969 kWh/gal (Kitchen), 0.0919 kWh/gal (Unknown)

8.33 = Specific weight of water (lbs/gallon)

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

WaterTemp = Assumed temperature of mixed water

= 86F for Bath, 93F for Kitchen 91F for Unknown[586]

SupplyTemp = Assumed temperature of water entering house

= 54.1F [587]

RE_electric = Recovery efficiency of electric water heater

[583] Because faucet usages are at times dictated by volume, only usage of the sort that would go straight down the drain will provide savings. VEIC is unaware of any metering study that has determined this specific factor and so through consensus with the Illinois Technical Advisory Group have deemed these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*0.75)+(0.3*0.9)=0.795.

[584] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

[585] Ibid.

[586] 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.

[587] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.

= 98% [588]

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 - Single Family	0.95[589]
Direct Install – Multi Family Kitchen	0.91[590]
Direct Install – Multi Family Bathroom	0.95[591]
Efficiency Kit Bathroom Aerator	0.63[592]
Efficiency Kit Kitchen Aerator	0.60[593]
Distributed School Efficiency Kit Aerator	To be determined through evaluation

For example, a direct installed kitchen low flow faucet aerator in a single-family electric DHW home:

ΔkWh = 1.0 * (((1.39 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.0969 * 0.95

= 131 kWh

For example, a direct installed bath low flow faucet aerator in a multi-family electric DHW home:

ΔkWh = 1.0 * (((1.39 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.0795 * 0.95

= 25.0 kWh

For example, a direct installed low flow faucet aerator in unknown faucet in a single-family electric DHW home:

ΔkWh = 1.0 * (((1.39 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.0919 * 0.95

= 68.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh / Hours * CF

Where:

[588] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx
[589] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8
[590] Navigant, ComEd-Nicor Gas EPY4/GPY1 Multi-Family Home Energy Savings Program Evaluation Report DRAFT 2013-01-28
[591] Ibid.
[592] From Navigant memo, "Nicor Gas energySMART Energy Saving Kits Program In Service Rate and Process Analysis", August 28, 2015.
[593] Ibid.

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for faucet use per faucet

= ((GPM_base * L_base) * Household/FPH * 365.25 * DF) * 0.545[594] / GPH

Building Type	Faucet location	Calculation	Hours per faucet
Single Family	Kitchen	((1.39 * 4.5) * 2.56/1 * 365.25 * 0.75) * 0.545 / 25.5	94
	Bathroom	((1. 39 * 1.6) * 2.56/2.83 * 365.25 * 0.9) * 0.545 / 25.5	14
	Unknown	((1. 39 * 9.0) * 2.56/3.83 * 365.25 * 0.795) * 0.545 / 25.5	52
Multi Family	Kitchen	((1. 39 * 4.5) * 2.1/1 * 365.25 * 0.75) * 0.545 / 25.5	77
	Bathroom	((1. 39 * 1.6) * 2.1/1.5 * 365.25 * 0.9) * 0.545 / 25.5	22
	Unknown	((1. 39 * 6.9) * 2.1/2.5 * 365.25 * 0.795) * 0.545 / 25.5	50

GPH = Gallons per hour recovery of electric water heater calculated for 70.9F temp rise (125-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 25.5

CF = Coincidence Factor for electric load reduction

= 0.022[595]

For example, a direct installed kitchen low flow faucet aerator in a single family electric DHW home:

ΔkW = 131/94 * 0.022

= 0.0306 kW

NATURAL GAS SAVINGS

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_gas * ISR

Where:

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

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[596]

EPG_gas = Energy per gallon of Hot water supplied by gas

[594] 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90F mixed faucet water.

[595] Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% *180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022

[596] 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

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

= 0.00341 Therm/gal for SF homes (Bath), 0.00415 Therm/gal for SF homes (Kitchen), 0.00394 Therm/gal for SF homes (Unknown)

= 0.00397 Therm/gal for MF homes (Bath), 0.00484 Therm/gal for MF homes (Kitchen), 0.00459 Therm/gal for MF homes (Unknown)

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[597]

= 67% For MF homes[598]

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

Other variables as defined above.

For example, a direct-installed kitchen low flow faucet aerator in a fuel DHW single-family home:

ΔTherms = 1.0 * (((1.39 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.00415 * 0.95

= 5.60 Therms

For example, a direct installed bath low flow faucet aerator in a fuel DHW multi-family home:

ΔTherms = 1.0 * (((1.39 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.003974 * 0.95

= 1.25 Therms

For example, a direct installed low flow faucet aerator in unknown faucet in a fuel DHW single-family home:

ΔTherms = 1.0 * (((1.39 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.00394 * 0.95

= 2.94 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Variables as defined above

597 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%.

598 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.

For example, a direct-installed kitchen low flow aerator in a single family home

$$\Delta gallons = (((1.39 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.95$$

$$= 1350 \text{ gallons}$$

For example, a direct installed bath low flow faucet aerator in a multi-family home:

$$\Delta gallons = (((1.39 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.95$$

$$= 314 \text{ gallons}$$

For example, a direct installed low flow faucet aerator in unknown faucet in a single-family home:

$$\Delta gallons = (((1.39 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.95$$

$$= 747 \text{ gallons}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES

Source ID	Reference
1	2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011.
2	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
3	1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999.
4	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
5	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
6	2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011.
7	2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.

MEASURE CODE: RS-HWE-LFFA-V06-180101

REVIEW DEADLINE: 1/1/2021

5.4.5 Low Flow Showerheads

Description

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

This measure may be used for units provided through Efficiency 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 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 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.[599]

Deemed Measure Cost

For time of sale or new construction the incremental cost for this measure is $7[600] or program actual.

For low flow showerheads provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $12[601] for Direct Install and $7 for Efficiency Kits.

Loadshape

Loadshape R03 - Residential Electric DHW

Coincidence Factor

The coincidence factor for this measure is assumed to be 2.78%.[602]

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[599] 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"

[600] Market research average of $7.

[601] Includes assess and install labor time of $5 (20min @ $15/hr)

[602] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period, where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture

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

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%603

GPM_base = Flow rate of the baseline showerhead

Program	GPM_base
Direct-install	2.67[604]
Retrofit, Efficiency Kits, NC or TOS	2.35[605]

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[606]

L_base = Shower length in minutes with baseline showerhead

= 7.8 min[607]

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603 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

604 Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above.

605 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.

606 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.

607 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

L_low = Shower length in minutes with low-flow showerhead

= 7.8 min[608]

Household = Average number of people per household

Household Unit Type[609]	Household
Single-Family - Deemed	2.56[610]
Multi-Family - Deemed	2.1[611]
Custom	Actual Occupancy or Number of Bedrooms[612]

SPCD = Showers Per Capita Per Day

= 0.6[613]

365.25 = Days per year, on average.

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

Household Type	SPH
Single-Family	1.79[614]
Multi-Family	1.3[615]
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 – 54.1)) / (0.98 * 3412)

= 0.117 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

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

ShowerTemp = Assumed temperature of water

= 101F [616]

for efficient showerhead and faucet aerators.

608 Ibid.

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

610 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

611 ComEd PY3 Multi-Family Evaluation Report REVISED DRAFT v5 2011-12-08.docx

612 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.

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

614 Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

615 Ibid.

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

SupplyTemp = Assumed temperature of water entering house

= 54.1F [617]

RE_electric = Recovery efficiency of electric water heater

= 98% [618]

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 - Single Family	0.98[619]
Direct Install – Multi Family	0.95[620]
Efficiency Kits--One showerhead kit	0.65[621]
Efficiency Kits—Two showerhead kit	0.67[622]
Distributed School Efficiency Kit showerhead	To be determined through evaluation

For example, a direct-installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:

ΔkWh = 1.0 * ((2.67 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.117 * 0.98

= 328 kWh

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) * Household * SPCD * 365.25) * 0.712[623] / GPH

= 302 for SF Direct Install; 248 for MF Direct Install

= 266 for SF Retrofit, Efficiency Kits, NC and TOS; 218 for MF Retrofit, Efficiency Kits, NC and TOS

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

617 US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.

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

619 Deemed values are from ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8. Alternative ISRs may be developed for program delivery methods based on evaluation results.

620 Navigant, ComEd-Nicor Gas EPY4/GPY1 Multi-Family Home Energy Savings Program Evaluation Report FINAL 2013-06-05

621 From Navigant memo, "Nicor Gas energySMART Energy Saving Kits Program In Service Rate and Process Analysis", August 28, 2015.

622 Ibid

623 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

= 27.51

CF = Coincidence Factor for electric load reduction

= 0.0278[624]

For example, a direct installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:

ΔkW = 328/302 * 0.0278

= 0.0302 kW

NATURAL GAS SAVINGS

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

Where:

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

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[625]

EPG_gas = Energy per gallon of Hot water supplied by gas

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

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[626]

= 67% For MF homes[627]

[624] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

[625] 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

[626] 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%.

[627] 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.

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

Other variables as defined above.

For example, a direct installed 1.5 GPM low flow showerhead in a gas fired DHW single family home where the number of showers is not known:

ΔTherms = 1.0 * ((2.67 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98

= 14.0 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

Δgallons = ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

For example, a direct installed 1.5 GPM low flow showerhead in a single family home where the number of showers is not known:

Δgallons = ((2.67 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98

= 2803 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES

Source ID	Reference
1	2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011.
2	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
3	1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999.
4	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
5	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
6	2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011.
7	2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.

MEASURE CODE: RS-HWE-LFSH-V05-180101

REVIEW DEADLINE: 1/1/2023

5.4.6 Water Heater Temperature Setback

Description

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

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

Definition of Efficient Equipment

High efficiency is a hot water tank with the thermostat reduced to no lower than 120 degrees.

Definition of Baseline Equipment

The baseline condition is a hot water tank with a thermostat setting that is higher than 120 degrees, typically systems with settings of 130 degrees or higher. Note if there are more than one DHW tanks in the home at or higher than 130 degrees and they are all turned down, then the savings per tank can be multiplied by the number of tanks.

Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 2 years.

Deemed Measure Cost

The incremental cost of a setback is assumed to be $5 for contractor time, or no cost if the measure is self-installed.

Loadshape

Loadshape R03 - Residential Electric DHW

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 1.

Algorithm

Calculation of Savings

Electric Energy Savings

For homes with electric DHW tanks:

ΔkWh[628] = (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)

Where:

U = Overall heat transfer coefficient of tank (Btu/Hr-°F-ft^2).

= Actual if known. If unknown assume R-12, U = 0.083

A = Surface area of storage tank (square feet)

[628] Note this algorithm provides savings only from reduction in standby losses. The TAC considered avoided energy from not heating the water to the higher temperature but determined that dishwashers are likely to boost the temperature within the unit (roughly canceling out any savings), faucet and shower use is likely to be at the same temperature so there would need to be more lower temperature hot water being used (cancelling any savings) and clothes washers will only see savings if the water from the tank is taken without any temperature control. It was felt the potential impact was too small to be characterized.

= Actual if known. If unknown use table below based on capacity of tank. If capacity unknown assume 50 gal tank; A = 24.99ft^2

Capacity (gal)	A (ft^2)[629]
30	19.16
40	23.18
50	24.99
80	31.84

Tpre = Actual hot water setpoint prior to adjustment

Tpost = Actual new hot water setpoint, which may not be lower than 120 degrees

Default Hot Water Temperature Inputs	
Tpre	135
Tpost	120

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

ISR = In service rate of measure

= Dependant on program delivery method as listed in table below

Delivery method	ISR
Instructions provided in a Kit	To be determined through evaluation
All other	1.0

3412 = Conversion from Btu to kWh

RE_electric = Recovery efficiency of electric hot water heater

= 0.98 [630]

A deemed savings assumption, where site specific assumptions are not available would be as follows:

ΔkWh = (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (3412 * 0.98)

= 81.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW **=** ΔkWh / Hours * CF

Where:

Hours = 8766

CF = Summer Peak Coincidence Factor for measure

= 1

[629] Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

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

A deemed savings assumption, where site specific assumptions are not available would be as follows:

ΔkW = (81.6/ 8766) * 1

ΔkW default = 0.00931 kW

NATURAL GAS SAVINGS

For homes with gas water heaters:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (100,000 * RE_gas)

Where

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

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[631]

= 67% For MF homes[632]

A deemed savings assumption, where site specific assumptions are not available would be as follows:

For Single Family homes:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (RE_gas)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (100,000 * 0.78)

= 3.5 Therms

For Multi Family homes:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (RE_gas)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (100,000 * 0.67)

= 4.1 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-TMPS-V05-160601

REVIEW DEADLINE: 1/1/2022

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[631] 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%.

[632] 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.

5.4.7 Water Heater Wrap

DESCRIPTION

This measure relates to a Tank Wrap or insulation "blanket" that is wrapped around the outside of a hot water tank to reduce stand-by losses. This measure applies only for homes that have an electric water heater that is not already well insulated. Generally this can be determined based upon the appearance of the tank.[633]

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The measure is a properly installed, R-8 or greater insulating tank wrap to reduce standby energy losses from the tank to the surrounding ambient area.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a standard electric domestic hot water tank without an additional tank wrap. Gas storage water heaters are excluded due to the limitations of retrofit wrapping and the associated impacts on reduced savings and safety.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 5 years[634].

DEEMED MEASURE COST

The incremental cost for this measure will be the actual material cost of procuring and labor cost of installing the tank wrap.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

This measure assumes a flat loadshape and as such the coincidence factor is 1.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For electric DHW systems:

$$\Delta kWh = ((A_{base} / Rbase – A_{insul} / R_{insul}) * \Delta T * Hours) / (3412 * \eta DHW)$$

Where:

[633] Visually determine whether it is insulated by foam (newer, rigid, and more effective) or fiberglass (older, gives to gently pressure, and not as effective)
[634] This estimate assumes the tank wrap is installed on an existing unit with 5 years remaining life.

R_{base} = Overall thermal resistance coefficient prior to adding tank wrap (Hr-°F-ft^2/BTU).

R_{insul} = Overall thermal resistance coefficient after addition of tank wrap (Hr-°F-ft^2/BTU).

A_{base} = Surface area of storage tank prior to adding tank wrap (square feet)[635]

A_{insul} = Surface area of storage tank after addition of tank wrap (square feet)[636]

ΔT = Average temperature difference between tank water and outside air temperature (°F)

= 60°F [637]

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

3412 = Conversion from Btu to kWh

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [638]

The following table has default savings for various tank capacity and pre and post R-VALUES.

Capacity (gal)	Rbase	Rinsul	Abase (ft2)[639]	Ainsul (ft2)[640]	ΔkWh	ΔkW
30	8	16	19.16	20.94	171	0.0195
30	10	18	19.16	20.94	118	0.0135
30	12	20	19.16	20.94	86	0.0099
30	8	18	19.16	20.94	194	0.0221
30	10	20	19.16	20.94	137	0.0156
30	12	22	19.16	20.94	101	0.0116
40	8	16	23.18	25.31	207	0.0236
40	10	18	23.18	25.31	143	0.0164
40	12	20	23.18	25.31	105	0.0120
40	8	18	23.18	25.31	234	0.0268
40	10	20	23.18	25.31	165	0.0189
40	12	22	23.18	25.31	123	0.0140
50	8	16	24.99	27.06	225	0.0257
50	10	18	24.99	27.06	157	0.0179
50	12	20	24.99	27.06	115	0.0131
50	8	18	24.99	27.06	255	0.0291
50	10	20	24.99	27.06	180	0.0206
50	12	22	24.99	27.06	134	0.0153
80	8	16	31.84	34.14	290	0.0331
80	10	18	31.84	34.14	202	0.0231
80	12	20	31.84	34.14	149	0.0170
80	8	18	31.84	34.14	328	0.0374
80	10	20	31.84	34.14	232	0.0265
80	12	22	31.84	34.14	173	0.0198

[635] Area includes tank sides and top to account for typical wrap coverage.
[636] Ibid.
[637] Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.
[638] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx
[639] Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
[640] Assumptions from PA TRM. A_{insul} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh / 8766 * CF$$

Where:

ΔkWh = kWh savings from tank wrap installation

8766 = Number of hours in a year (since savings are assumed to be constant over year).

CF = Summer Coincidence Factor for this measure

= 1.0

The table above has default kW savings for various tank capacity and pre and post R-values.

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-HWE-WRAP-V02-150601

Review Deadline: 1/1/2022

5.4.8 Thermostatic Restrictor Shower Valve

Description

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years. [641]

Deemed Measure Cost

The incremental cost of the measure should be the actual program cost (including labor if applicable) or $30[642] plus $20 labor[643] if not available.

Loadshape

Loadshape R03 - Residential Electric DHW

Coincidence Factor

The coincidence factor for this measure is assumed to be 0.22%.[644]

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641 Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead

642 Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.

643 Estimate for contractor installation time.

644 Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%[645]

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

Program	GPM
Direct-install, device only	2.67[646]
New Construction or direct install of device and low flow showerhead	Rated or actual flow of program-installed showerhead
Retrofit or TOS	2.35[647]

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

= 0.89 minutes[648]

Household = Average number of people per household

Household Unit Type[649]	Household
Single-Family - Deemed	2.56[650]
Multi-Family - Deemed	2.1[651]
Custom	Actual Occupancy or Number of Bedrooms[652]

645 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

646 Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above. Assumes low flow showerhead not included in direct installation.

647 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.

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

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

650 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

651 ComEd PY3 Multi-Family Evaluation Report REVISED DRAFT v5 2011-12-08.docx

652 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

SPCD = Showers Per Capita Per Day

= 0.6[653]

365.25 = Days per year, on average.

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

Household Type	SPH
Single-Family	1.79[654]
Multi-Family	1.3[655]
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 – 54.1)) / (0.98 * 3412)

= 0.117 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

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

ShowerTemp = Assumed temperature of water

= 101F [656]

SupplyTemp = Assumed temperature of water entering house

= 54.1F [657]

RE_electric = Recovery efficiency of electric water heater

= 98% [658]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependent on program delivery method as listed in table below

Selection	ISR
Direct Install - Single Family	0.98[659]
Direct Install – Multi Family	0.95[660]
Efficiency Kits	To be determined through evaluation

[653] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[654] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
[655] Ibid.
[656] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[657] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html.
[658] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx
[659] Deemed values are from ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8. Alternative ISRs may be developed for program delivery methods based on evaluation results.
[660] Navigant, ComEd-Nicor Gas EPY4/GPY1 Multi-Family Home Energy Savings Program Evaluation Report FINAL 2013-06-05

EXAMPLE

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

ΔkWh = 1.0 * (2.67 * 0.89 * 2.56 * 0.6 * 365.25 / 1.79) * 0.117 * 0.98

= 85 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device

= ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25) * 0.712[661] / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

= 34.4 for SF Direct Install; 28.3 for MF Direct Install

= 30.3 for SF Retrofit and TOS; 24.8 for MF Retrofit and TOS

CF = Coincidence Factor for electric load reduction

= 0.0022[662]

EXAMPLE

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

ΔkW = 85.3/34.4 * 0.0022

= 0.0055 kW

NATURAL GAS SAVINGS

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

Where:

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

[661] 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

[662] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[663]

EPG_gas = Energy per gallon of Hot water supplied by gas

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

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[664]

= 67% For MF homes[665]

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

Other variables as defined above.

EXAMPLE

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

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

= 3.7 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Variables as defined above

663 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

664 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%.

665 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.

EXAMPLE

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

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

= 730 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES

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

MEASURE CODE: RS-HWE-TRVA-V03-180101

REVIEW DEADLINE: 1/1/2023

5.4.9 Shower Timer

Description

Shower Timers are designed to make it easy for people to consistently take short showers, resulting in water and energy savings.

The shower timer provides a reminder to participants on length of their shower visually or auditorily.

This measure was developed to be applicable to the following program type: KITS, DI.

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

Definition of Efficient Equipment

The shower timer should provide a reminder to participants to keep showers to a length of 5 minutes or less.

Definition of Baseline Equipment

The baseline is no shower timer.

Deemed Lifetime of Efficient Equipment

The deemed lifetime is 2 years[666].

Deemed Measure Cost

For shower timers provided in Efficiency Kits, the actual program delivery costs should be utilized.

Loadshape

Loadshape R03 - Residential Electric DHW

Coincidence Factor

The coincidence factor for this measure is assumed to be 2.78%.[667]

Algorithm

Calculation of Energy Savings

Electric Energy Savings

ΔkWh = %Electric DHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Electric

Where:

[666] Estimate of persistence of behavior change instigated by the shower timer.

[667] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period, where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

%Electric DHW = Proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%[668]

GPM = Flow rate of showerhead as used

= Custom, to be determined through evaluation. If data is not available use 1.93[669]

L_base = Number of minutes in shower without a shower timer

=7.8 minutes[670]

L_timer = Number of minutes in shower after shower timer

= Custom, to be determined through evaluation. If data is not available use 5.79[671]

Household = Number in household using timer

Household Unit Type[672]	Household
Single-Family - Deemed	2.56[673]
Multi-Family - Deemed	2.1[674]
Custom	Actual Occupancy or Number of Bedrooms[675]

Days/yr = 365.25

SPCD = Showers Per Capita Per Day

= 0.6[676]

UsageFactor = How often each participant is using shower timer

=Custom, to be determined through evaluation. If data is not available use 0.34[677]

EPG_Electric = Energy per gallon of hot water supplied by electric

668 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

669 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

670 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.

671 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

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

673 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

674 ComEd PY3 Multi-Family Evaluation Report REVISED DRAFT v5 2011-12-08.docx

675 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.

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

677 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

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

= (8.33 * 1.0 * (101 – 54.1)) / (0.98 * 3412)

=0.117 kWh/gal

Based on default assumptions provided above, the savings for a single family home would be:

ΔkWh = %Electric DHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Electric

= 0.16 * 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.117

=13.9kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) * Household Users * SPCD * 365.25) * 0.712 / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

CF = Coincidence Factor for electric load reduction

= 0.0278[678]

Based on default assumptions provided above, the savings for a single family home would be:

ΔkW = ΔkWh/Hours * CF

= 0.0013 kW

NATURAL GAS SAVINGS

ΔTherms = %FossilDHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas

%FossilDHW = Proportion of water heating supplied by electric resistance heating

DHW fuel	%FossilDHW
Electric	0%
Natural Gas	100%
Unknown	84%[679]

678 Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

679 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)

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes [680]

= 67% For MF homes[681]

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

Other variables as defined above.

Based on default assumptions provided above, the savings for a single family home would be:

Δ Therms = %FossilDHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas

= 0.84 * 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.00501

= 3.1 Therms

WATER DESCRIPTIONS AND CALCULATION

ΔGallons = GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor

Variables as defined above

Based on default assumptions provided above, the savings for a single family home would be:

ΔGallons = GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor

= 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34

= 740.0 gallons

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-DHW-SHTM-V01-180101

REVIEW DEADLINE: 1/1/2019

[680] 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%.

[681] 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.

5.5 Lighting End Use

5.5.1 Compact Fluorescent Lamp (CFL)

DESCRIPTION

A low wattage qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the CFL is installed in a residential location. If the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used[682].

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) required all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W in 2013 and 60W and 40W 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 exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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 qualified compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an EISA qualified incandescent or halogen as provided in the table provided in the Electric Energy Savings section.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) for bulbs installed in 2018 is assumed to be 3 years and then for every subsequent year should be reduced by one year[683].

[682] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112016.xls'.

[683] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost is $1.20[684].

For the Direct Install measure, the full cost of $2.45 per bulb should be used, plus $5 labor cost[685] for a total of $7.45 per bulb. However actual program delivery costs should be utilized if available.

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

LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1% for Time of Sale Residential and in-unit Multi Family bulbs, 27.3% for exterior bulbs and 8.1% for unknown[686] and 7.4% for Residential Direct Install[687].

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe

Where:

WattsBase = Based on lumens of CFL bulb and program year installed:

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Post-EISA 2007 (WattsBase)
5280	6209	300
3000	5279	200
2601	2999	150
1490	2600	72
1050	1489	53
750	1049	43
310	749	29
250	309	25

WattsEE = Actual wattage of CFL purchased / installed

[684] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
[685] Based on 15 minutes at $20 an hour. Includes some portion of travel time to site.
[686] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
[687] Based on lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation and excluding all logged bulbs installed in closets.

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

Program		Weighted Average 1st Year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Retail (Time of Sale)		76.5%[688]	11.6%	9.9%	98.0%[689]
Direct Install		96.9%[690]			
Efficiency Kits[691]	CFL Distribution[692]	59%	13%	11%	83%
	School Kits[693]	61%	13%	11%	86%
	Direct Mail Kits[694]	66%	14%	12%	93%

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[695]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation or use deemed assumptions below[696]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

[688] 1st year in service rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL RES Lighting ISR_112016.xls' for more information). The average first year ISR for each utility was calculated weighted by the number of bulbs in the each year's survey. This was then weighted by annual sales to give a statewide assumption.

[689] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[690] Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

[691] In Service Rates provided are for the CFL bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provided may be used.

[692] Free bulbs provided without request, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential CFL Distribution Program', Report Table 11 and Appendix B.

[693] Kits provided free to students through school, with education program. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10. Final ISR assumptions are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, and second and third year estimates based on same proportion of future installs.

[694] Opt-in program to receive kits via mail, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10, as above.

[695] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[696] Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

Hours = Average hours of use per year

Program Delivery	Installation Location	Hours[697]
Retail (Time of Sale) and Efficiency Kits	Residential Interior and in-unit Multi Family	759
	Exterior	2,475 [698]
	Unknown	847 [699]
Direct Install	Residential Interior and in-unit Multi Family	793
	Exterior	2,475

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

Bulb Location	WHFe
Interior single family or unknown location	1.06 [700]
Multi family in unit	1.04 [701]
Exterior or uncooled location	1.0

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

697 Except where noted, based on lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation. Direct Install value excludes all logged bulbs installed in closets.

698 Based on secondary research conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation.

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

700 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

701 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

For example, for a 14W CFL (60W standard incandescent and 43W EISA qualified incandescent/halogen):

$\Delta kWH_{1st\ year\ installs}$ = ((43 - 14) / 1000) * 0.765 * 847 * 1.06

= 19.9 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((43 - 14) / 1000) * 0.116 * 847 * 1.06

= 3.0 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((43 - 14) / 1000) * 0.099 * 847 * 1.06

= 2.6 kWh

HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[702] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / ηHeat

Where:

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

= 49%[703] for interior or unknown location

= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[704]:

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[705]	N/A	N/A	1.28

[702] Negative value because this is an increase in heating consumption due to the efficient lighting.
[703] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.
[704] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.
[705] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

For example, a 14W standard CFL is purchased and installed in home with 2.0 COP (including duct loss) Heat Pump:

$\Delta kWh_{1st\ year}$ = - (((43 - 14) / 1000) * 0.765 * 759 * 0.49) / 2.0

= - 4.2 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

Bulb Location	WHFd
Interior single family or unknown location	1.11[706]
Multi family in unit	1.07[707]
Exterior or uncooled location	1.0

CF = Summer Peak Coincidence Factor for measure.

Program Delivery	Bulb Location	CF[708]
Retail(Time of Sale)	Interior single family or Multi Family in unit	7.1%
	Exterior	27.3%
	Unknown location	8.1%
Direct Install	Residential	7.4%

Other factors as defined above

For example, a 14W standard CFL is purchased and installed in a single family interior location:

ΔkW = ((43 - 14) / 1000) * 0.765 * 1.11 * 0.071

= 0.0017 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

[706] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[707] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[708] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. Direct Install value is based on resut excluding all logged bulbs installed in closets.

NATURAL GAS SAVINGS

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

ΔTherms[709] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49%[710] for interior or unknown location

= 0% for exterior or unheated location

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[711]

For example, a 14 standard CFL is purchased and installed in a home:

ΔTherms = - (((43 - 14) / 1000) * 0.765 * 759 * 0.49 * 0.03412) / 0.7

= - 0.40 Therms

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

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:

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

710 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

711 This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

Program Delivery	Installation Location	Replacement Period (years)[712]	Replacement Cost[713]
Retail (Time of Sale) and Efficiency Kits	Residential Interior and in-unit Multi Family	1.3	$1.25
	Exterior	0.4	
	Unknown	1.2	
Direct Install	Residential Interior and in-unit Multi Family	1.3	
	Exterior	0.4	

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs are actually in service and so should be multiplied by the appropriate ISR.

MEASURE CODE: RS-LTG-ESCF-V06-180101

REVIEW DEADLINE: 1/1/2020

[712] 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).

[713] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

5.5.2 ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

DESCRIPTION

A qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb.

Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the specialty CFL is installed in a residential location. If the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used[714].

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 qualified specialty compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a specialty incandescent light bulb including those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (<40W), candelabra base (<60W), vibration service bulb, decorative candle with medium or intermediate base (<40W), shatter resistant and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5" diameter and >40W), candle (shapes B, BA, CA >40W, candelabra base lamps (>60W) and intermediate base lamps (>40W).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6.8 year[715] for bulbs exempt from EISA, or 3 years for bulbs non-exempt installed in 2018 and then for every subsequent year should be reduced by one year[716].

DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $5[717].

For the Direct Install measure, the full cost of $8.50 should be used plus $5 labor[718] for a total of $13.50. However

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[714] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112015.xls'.

[715] The assumed measure life for the specialty bulb measure characterization was reported in "Residential Lighting Measure Life Study", Nexus Market Research, June 4, 2008 (measure life for markdown bulbs). Measure life estimate does not distinguish between equipment life and measure persistence. Measure life includes products that were installed and operated until failure (i.e., equipment life) as well as those that were retired early and permanently removed from service for any reason, be it early failure, breakage, or the respondent not liking the product (i.e., measure persistence).

[716] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

[717] NEEP Residential Lighting Survey, 2011

[718] Based on 15 minutes at $20 per hour.

actual program delivery costs should be utilized if available.

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

LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

COINCIDENCE FACTOR

Unlike standard CFLs that could be installed in any room, certain types of specialty CFLs are more likely to be found in specific rooms, which affects the coincident peak factor. Coincidence factors by bulb types are presented below[719]

Bulb Type	Peak CF
Three-way	0.078[720]
Dimmable	0.078[721]
Interior reflector (incl. dimmable)	0.091
Exterior reflector	0.273
Candelabra base and candle medium and intermediate base	0.121
Bug light	0.273
Post light (>100W)	0.273
Daylight	0.081
Plant light	0.081
Globe	0.075
Vibration or shatterproof	0.081
Standard spirals >= 2601 lumens, Residential, Multi-family in unit	0.071
Standard spirals >= 2601 lumens, unknown	0.081
Standard spirals >= 2601 lumens, exterior	0.273
Specialty - Generic	0.081

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe$$

Where:

WattsBase = Actual wattage equivalent of incandescent specialty bulb, use the tables below to obtain the incandescent bulb equivalent wattage[722]; use 60W if unknown[723]

[719] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[720] Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[721] Ibid

[722] Based upon the draft ENERGY STAR specification for lamps (http://energystar.gov/products/specs/sites/products/files/ENERGY_STAR_Lamps_V1_0_Draft%203.pdf) and the Energy Policy and Conservation Act of 2012.

[723] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

EISA exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Standard Spirals >=2601	2601	2999	150
	3000	5279	200
	5280	6209	300
3-Way	250	449	25
	450	799	40
	800	1099	60
	1100	1599	75
	1600	1999	100
	2000	2549	125
	2550	2999	150
Globe (medium and intermediate bases less than 750 lumens)	90	179	10
	180	249	15
	250	349	25
	350	749	40
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10
	90	149	15
	150	299	25
	300	749	40
Globe (candelabra bases less than 1050 lumens)	90	179	10
	180	249	15
	250	349	25
	350	499	40
	500	1049	60
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10
	90	149	15
	150	299	25
	300	499	40
	500	1049	60

Directional Lamps - ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for lamps with rated wattages less than 20Wand 50 Lm/W for lamps with rated wattages >= 20 watts[724].

For Directional R, BR, and ER lamp types[725]:

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$
R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40
	473	524	45
	525	714	50
	715	937	65
	938	1259	75
	1260	1399	90
	1400	1739	100
	1740	2174	120

[724] From pg 10 of the Energy Star Specification for lamps v1.1
[725] From pg 11 of the Energy Star Specification for lamps v1.1

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$
	2175	2624	150
	2625	2999	175
	3000	4500	200
***R, BR, and ER with medium screw bases w/ diameter <=2.25"**	400	449	40
	450	499	45
	500	649	50
	650	1199	65
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40
	450	719	45
***All reflector lamps below lumen ranges specified above**	200	299	20
	300	399	30

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[726] If CBCP and beam angle information are not available, or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[727]

$$\text{Wattsbase} =$$

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

Diameter	Permitted Wattages
16	20, 35, 40, 45, 50, 60, 75
20	50
30S	40, 45, 50, 60, 75
30L	50, 75
38	40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250

EISA non-exempt bulb types:

[726] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

[727] The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

Bulb Type	Lower Lumen Range	Upper Lumen Range	Incandescent Equivalent Post-EISA 2007 (WattsBase)
Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	310	749	29
	750	1049	43
	1050	1489	53
	1490	2600	72

WattsEE = Actual wattage of energy efficient specialty bulb purchased, use 15W if unknown[728]

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

Program		Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Retail (Time of Sale)		88.0%[729]	5.4%	4.6%	98.0%[730]
Direct Install		96.9%[731]			
Efficiency Kits[732]	CFL Distribution[733]	59%	13%	11%	83%
	School Kits[734]	61%	13%	11%	86%
	Direct Mail Kits[735]	66%	14%	12%	93%

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if

[728] An evaluation (Energy Efficiency / Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: Residential Energy Star ® Lighting) reported 13-17W as the most common specialty CFL wattage (69% of program bulbs). 2009 California data also reported an average CFL wattage of 15.5 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program, Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009).

[729] 1st year in service rate is based upon review of PY4-6 evaluations from ComEd and PY5-6 from Ameren (see 'IL RES Lighting ISR_122014.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.

[730] The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[731] Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

[732] In Service Rates provided are for the bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provide may be used.

[733] Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

[734] Kits provided free to students through school, with education program. Consistent with Standard CFL assumptions.

[735] Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

deemed appropriate[736]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[737]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year, varies by bulb type as presented below:[738]

Bulb Type	Annual hours of use (HOU)
Three-way	850
Dimmable	850
Interior reflector (incl. dimmable)	861
Exterior reflector	2475
Candelabra base and candle medium and intermediate base	1190
Bug light	2475
Post light (>100W)	2475
Daylight	847
Plant light	847
Globe	639
Vibration or shatterproof	847
Standard Spiral >2601 lumens, Residential, Multi Family in-unit	759
Standard Spiral >2601 lumens, unknown	847
Standard Spiral >2601 lumens, Exterior	2475
Specialty - Generic	847

WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting

Bulb Location	WHFe
Interior single family or unknown location	1.06 [739]

[736] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[737] Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

[738] Hours of use by specialty bulb type calculated using the average hours of use in locations or rooms where each type of specialty bulb is most commonly found. Values for Reflector, Decorative and Globe are taken directly from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. All other hours have been updated based on the room specific hours of use from the PY5/PY6 logger study.

[739] The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest

Bulb Location	WHFe
Multi family in unit	1.04 [740]
Exterior or uncooled location	1.0

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

For example, for a 13W dimmable CFL impacted by EISA 2007 (60W standard incandescent and 43W EISA qualified incandescent/halogen).

$\Delta kWH_{1st\ year\ installs}$ = ((60 - 13) / 1000) * 0.823 * 850 * 1.06

= 34.9 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((43 - 13) / 1000) * 0.085 * 850 * 1.06

= 2.3 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((43 - 13) / 1000) * 0.072 * 850 * 1.06

= 1.9 kWh

Note: delta watts is equivalent to install year. Here we assume no change in hours assumption.

HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[741] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / ηHeat

Where:

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

= 49%[742] for interior or unknown location

= 0% for exterior location

ηHeat = Efficiency in COP of Heating equipment

Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

740 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).

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

742 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

= actual. If not available use[743]:

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[744]	N/A	N/A	1.28

For example, a 15W globe CFL replacing a 60W incandescent specialty bulb installed in home with 2.0 COP Heat Pump (including duct loss):

$\Delta kWh_{1st\ year}$ = - (((60 - 15) / 1000) * 0.823 * 639 * 0.49) / 2.0

= - 5.8 kWh

Second and third year savings should be calculated using the appropriate ISR.

Summer Coincident Peak Demand Savings

ΔkW =((WattsBase - WattsEE) / 1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

Bulb Location	WHFd
Interior single family or unknown location	1.11[745]
Multi family in unit	1.07[746]
Exterior or uncooled location	1.0

CF = Summer Peak Coincidence Factor for measure. Coincidence factors by bulb types are presented below[747]

[743] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[744] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

[745] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[746] As above but using estimate of 45% of multifamily buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average); http://205.254.135.7/consumption/residential/data/2009/xls/HC7.1%20Air%20Conditioning%20by%20Housing%20Unit%20Type.xls.

[747] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

Bulb Type	Peak CF
Three-way	0.078[748]
Dimmable	0.078[749]
Interior reflector (incl. dimmable)	0.091
Exterior reflector	0.273
Candelabra base and candle medium and intermediate base	0.121
Bug light	0.273
Post light (>100W)	0.273
Daylight	0.081
Plant light	0.081
Globe	0.075
Vibration or shatterproof	0.081
Standard Spiral >=2601 lumens, Residential, Multi-family in unit	0.071
Standard spirals >= 2601 lumens, unknown	0.081
Standard spirals >= 2601 lumens, exterior	0.273
Specialty - Generic	0.081

Other factors as defined above

For example, a 15W specialty CFL replacing a 60W incandescent specialty bulb:

$\Delta kW_{1st\ year}$ = ((60 - 15) / 1000) * 0.823 * 1.11 * 0.081

= 0.003 kW

Second and third year savings should be calculated using the appropriate ISR.

NATURAL GAS SAVINGS

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

ΔTherms[750] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / ηHeat

Where:

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

= 49%[751] for interior or unknown location

= 0% for exterior location

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[752]

748 Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

749 Ibid

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

751 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

752 This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on 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

For example, a 15W Globe specialty CFL replacing a 60W incandescent specialty bulb:

ΔTherms = - (((60 - 15) / 1000) * 0. 823 * 639 * 0.49 * 0.03412) / 0.7

= - 0.57 Therms

Second and third year savings should be calculated using the appropriate ISR.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The following O&M assumptions should be used: Life of the baseline bulb is assumed to be 1.32 year[753]; baseline replacement cost is assumed to be $3.5[754].

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

MEASURE CODE: RS-LTG-ESCC-V05-180101

REVIEW DEADLINE: 1/1/2020

market or geographical area then that should be used.)

In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[753] Assuming 1000 hour rated life for incandescent bulb: 1000/759 = 1.32

[754] NEEP Residential Lighting Survey, 2011

5.5.3 ENERGY STAR Torchiere

Description

A high efficiency ENERGY STAR fluorescent torchiere is purchased in place of a baseline mix of halogen and incandescent torchieres and installed in a residential setting.

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 fluorescent torchiere must meet ENERGY STAR efficiency standards.

Definition of Baseline Equipment

The baseline is based on a mix of halogen and incandescent torchieres.

Deemed Lifetime of Efficient Equipment

The lifetime of the measure is assumed to be 8 years[755].

Deemed Measure Cost

The incremental cost for this measure is assumed to be $5[756].

Loadshape

Loadshape R06 - Residential Indoor Lighting
Loadshape R07 - Residential Outdoor Lighting

Coincidence Factor

The summer peak coincidence factor for this measure is 7.1% for Residential and in-unit Multi Family bulbs and 8.1% for bulbs installed in unknown locations[757].

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = ((\Delta Watts)/1000) * ISR * (1-Leakage) * HOURS * WHFe$$

Where:

ΔWatts = Average delta watts per purchased ENERGY STAR torchiere

= 115.8 [758]

[755] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[756] DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com) and consistent with Efficiency Vermont TRM.
[757] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
[758] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting

ISR = In Service Rate or percentage of units rebated that get installed.

= 0.86 [759]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[760]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[761]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

HOURS = Average hours of use per year

Installation Location	Hours
Residential and in-unit Multi Family	1095 (3.0 hrs per day)[762]

WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting

Bulb Location	WHFe
Interior single family or unknown location	1.06 [763]
Multi family in unit	1.04 [764]
Exterior or uncooled location	1.0

For single family buildings:

ΔkWh = (115.8 /1000) * 0.86 * 1095 * 1.06

= 116 kWh

Programs", Final Report, October 1, 2004, p. 43 (Table 4-9)

[759] Nexus Market Research, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs" table 6-3 on p63 indicates that 86% torchieres were installed in year one. http://publicservice.vermont.gov/energy/ee_files/efficiency/eval/marivtreportfinal100104.pdf

[760] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[761] Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

[762] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 104 (Table 9-7)

[763] The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[764] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

For multi family in unit:

ΔkWh = (115.8 /1000) * 0.86 * 1095 * 1.04

= 113 kWh

HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[765] = - ((ΔWatts) /1000) * ISR * HOURS * HF) / ηHeat

Where:

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

= 49%[766] for interior or unknown location

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use defaults provided below[767]:

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[768]	N/A	N/A	1.28

For example, an ES torchiere installed in a house with a 2016 heat pump:

ΔkWh = - ((115.8) / 1000) * 0.86 * 1095 * 0.49) / 2.04

= - 26.2 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((ΔWatts) /1000) * ISR * WHFd * CF

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting

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

766 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

767 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

768 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

Bulb Location	WHFd
Interior single family or unknown location	1.11[769]
Multi family in unit	1.07[770]
Exterior or uncooled location	1.0

CF = Summer Peak Coincidence Factor for measure

Bulb Location	CF[771]
Interior single family or Multi family in unit	7.1%
Unknown location	8.1%

For single family and multi-family in unit buildings:

ΔkW = (115.8 / 1000) * 0.86 * 1.11 * 0.071

= 0.008kW

For unknown location:

ΔkW = (115.8 / 1000) * 0.86 * 1.07 * 0.081

= 0.009 kW

NATURAL GAS SAVINGS

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

$\Delta Therms_{WH}$ = - (((ΔWatts) /1000) * ISR * HOURS * 0.03412 * HF) / ηHeat

Where:

$\Delta Therms_{WH}$ = gross customer annual heating fuel increased usage for the measure from the reduction in lighting heat in therms.

0.03412 = conversion from kWh to therms

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

= 49% [772]

ηHeat = average heating system efficiency

= 70% [773]

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[769] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[770] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[771] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[772] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

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

$\Delta Therms_{WH}$ = - ((115.8 / 1000) * 0.86 * 1095 * 0.03412 * 0.49) / 0.70

= - 2.60 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Life of the baseline bulb is assumed to be 1.83 years[774] for residential and multifamily in unit. Baseline bulb cost replacement is assumed to be $6.[775]

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

MEASURE CODE: RS-LTG-ESTO-V04-180101

REVIEW DEADLINE: 1/1/2020

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[774] Based on VEIC assumption of baseline bulb (mix of incandescent and halogen) average rated life of 2000 hours, 2000/1095 = 1.83 years.

[775] Derived from Efficiency Vermont TRM.

5.5.4 Exterior Hardwired Compact Fluorescent Lamp (CFL) Fixture

Description

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an exterior residential setting. This measure could relate to either a fixture replacement or new installation (i.e. time of sale).

Federal legislation stemming from the Energy Independence and Security Act of 2007 required all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ends in 2012, followed by restrictions on 75W in 2013 and 60W and 40W 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 exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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 condition is an ENERGY STAR lighting exterior fixture for pin-based compact fluorescent lamps.

Definition of Baseline Equipment

The baseline condition is a standard EISA qualified incandescent or halogen exterior fixture as provided in the table provided in the Electric Energy Savings section.

Deemed Lifetime of Efficient Equipment

The expected life of an exterior fixture is 20 years[776]. However due to the backstop provision in the Energy Independence and Security Act of 2007 that requires by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, the baseline replacement would become a CFL in that year. The expected measure life for CFL fixtures installed in 2018 is therefore assumed to be 3 years. For bulbs installed in 2019, this would be reduced to 2 years[777].

Deemed Measure Cost

The incremental cost for an exterior fixture is assumed to be $32[778].

Loadshape

Loadshape R07 - Residential Outdoor Lighting

[776] 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) gives 20 years for an interior fluorescent fixture.
[777] Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.
[778] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for exterior fixture (http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?4349-303e=&b6b3-3efd&b6b3-3efd)

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 27.3%[779].

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh =((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours

Where:

WattsBase = Based on lumens of CFL bulb and program year purchased:

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Post-EISA 2007 (WattsBase)
5280	6209	300
3000	5279	200
2601	2999	150
1490	2600	72
1050	1489	53
750	1049	43
310	749	29
250	309	25

WattsEE = Actual wattage of CFL purchased

ISR = In Service Rate or the percentage of units rebated that get installed.

Program	Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Retail (Time of Sale)	87.5%[780]	5.7%	4.8%	98.0%[781]
Direct Install	96.9[782]			

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if

[779] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[780] 1st year in service rate is based upon review of PY2-3 evaluations from ComEd (see 'IL RES Lighting ISR.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.

[781] The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[782] In the absence of evaluation results for Direct Install Fixtures specifically, this is made consistent with the Direct Install CFL measure which is based upon review of the PY2 and PY3 ComEd Direct Install program surveys.

deemed appropriate[783]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[784]:

ComEd: 1.05%

Ameren: 6.55%

All other programs = 0

Hours = Average hours of use per year

=2475 (6.78 hrs per day)[785]

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

For example, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen).

$\Delta kWH_{1st\ year\ installs}$ = ((86 - 28) / 1000) * 0.875 * 2475

= 125.6 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((86 - 28) / 1000) * 0.057 * 2475

= 8.2 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((86 - 28) / 1000) * 0.048 * 2475

= 6.9 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * CF

Where:

[783] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[784] Leakage rate is based upon TAC agreed 50% of the lamp leakage assumptions (based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information)).

[785] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

CF = Summer Peak Coincidence Factor for measure.

= 27.3%[786]

Other factors as defined above

For example, a 2 x 14W pin-based CFL fixture:

$\Delta kW_{1st\ year}$ = ((86 - 28) / 1000) * 0.875 * 0.273

= 0.0142 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Life of the baseline bulb is assumed to be 0.4 years[787] for exterior applications. Baseline bulb cost replacement is assumed to be $1.25.[788]

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

MEASURE CODE: RS-LRG-EFOX-V06-180101

REVIEW DEADLINE: 1/1/2020

[786] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
[787] 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).
[788] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

5.5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture

Description

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an interior residential setting. This measure could relate to either a fixture replacement or new installation (i.e. time of sale).

Federal legislation stemming from the Energy Independence and Security Act of 2007 required all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ends in 2012, followed by restrictions on 75W in 2013 and 60W and 40W 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 exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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 condition is an ENERGY STAR lighting interior fixture for pin-based compact fluorescent lamps.

Definition of Baseline Equipment

The baseline condition is a standard EISA qualified incandescent or halogen interior fixture as provided in the table provided in the Electric Energy Savings section.

Deemed Lifetime of Efficient Equipment

The expected life of an interior fixture is 20 years[789]. However due to the backstop provision in the Energy Independence and Security Act of 2007 that requires by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, the baseline replacement would become equivalent to a CFL in that year. The expected measure life for CFL fixtures installed in 2018 is therefore assumed to be 3 years. For bulbs installed in 2019, this would be reduced to 2 years and should be reduced each year[790].

Deemed Measure Cost

The incremental cost for an interior fixture is assumed to be $32[791].

Loadshape

Loadshape R06 - Residential Indoor Lighting

[789] 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) gives 20 years for an interior fluorescent fixture.

[790] Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

[791] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture (http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?4349-303e=&b6b3-3efd&b6b3-3efd)

Coincidence Factor

The summer peak coincidence factor is assumed to be 7.1%[792] for Residential and in-unit Multi Family bulbs.

Algorithm

Calculation of Savings

Electric Energy Savings

ΔkWh = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe

Where:

WattsBase = Based on lumens of CFL bulb and program year purchased:

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Post-EISA 2007 ($Watts_{Base}$)
5280	6209	300
3000	5279	200
2601	2999	150
1490	2600	72
1050	1489	53
750	1049	43
310	749	29
250	309	25

WattsEE = Actual wattage of CFL purchased

ISR = In Service Rate or the percentage of units rebated that get installed.

Program	Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Retail (Time of Sale)	87.5%[793]	5.7%	4.8%	98.0%[794]
Direct Install	96.9[795]			

[792] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[793] 1st year in service rate is based upon review of PY2-3 evaluations from ComEd (see 'IL RES Lighting ISR.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.

[794] The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[795] In the absence of evaluation results for Direct Install Fixtures specifically, this is made consistent with the Direct Install CFL measure which is based upon review of the PY2 and PY3 ComEd Direct Install program surveys.

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[796]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[797]:

ComEd: 1.05%

Ameren: 6.55%

All other programs = 0

Hours = Average hours of use per year

Installation Location	Hours
Residential and in-unit Multi Family	759 [798]

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

Bulb Location	WHFe
Interior single family or unknown location	1.06 [799]
Multi family in unit	1.04 [800]

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

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[796] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[797] Leakage rate is based upon TAC agreed 50% of the lamp leakage assumptions (based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information)).

[798] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[799] The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[800] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

For example, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen):

$\Delta kWH_{1st\ year\ installs}$ = ((86 - 28) / 1000) * 0.875 * 759 * 1.06

= 40.8 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((86 - 28) / 1000) * 0.057 * 759 * 1.06

= 2.7 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((86 - 28) / 1000) * 0.048 * 759 * 1.06

= 2.2 kWh

HEATING PENALTY

If electric heated building:

ΔkWh[801] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / ηHeat

Where:

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

= 49%[802] for interior or unknown location

= 0% for unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[803]:

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[804]	N/A	N/A	1.28

801 Negative value because this is an increase in heating consumption due to the efficient lighting.
802 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.
803 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.
804 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

For example, a 2 x 14W pin-based CFL fixture is purchased and installed in home with 2.0 COP (including duct loss) Heat Pump:

$\Delta kWh_{1st\ year}$ = - (((86 – 28) / 1000) * 0.875 * 759 * 0.49) / 2.0

= - 9.4 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

Bulb Location	WHFd
Interior single family or unknown location	1.11[805]
Multi family in unit	1.07[806]
Exterior or uncooled location	1.0

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF[807]
Interior single family or unknown location	7.1%
Multi family in unit	7.1%

Other factors as defined above

For example, a 14W pin-based CFL fixture:

$\Delta kW_{1st\ year}$ = ((86- 28) / 1000) * 0.875 * 1.11 * 0.071

= 0.004 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

NATURAL GAS SAVINGS

$\Delta Therms$[808] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / ηHeat

Where:

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

[805] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.
[806] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)
[807] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
[808] Negative value because this is an increase in heating consumption due to the efficient lighting.

= 49%[809] for interior or unknown location

= 0% for unheated location

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[810]

For example, a 2 x 14W pin-based CFL fixture is purchased and installed in home with gas heat at 70% efficiency:

$\Delta Therms_{1st\ year}$ = -((86 - 28) / 1000) * 0.875 * 759 * 0.49 * 0.03412) / 0.7

= - 0.9 Therms

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Life of the baseline bulb is assumed to be 1.3 years[811] for interior applications. Baseline bulb cost replacement is assumed to be $1.25.[812]

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

MEASURE CODE: RS-LTG-IFIX-V06-180101

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809 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

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

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

811 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).

812 Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

5.5.6 LED Specialty Lamps

Description

This measure describes savings from a variety of specialty LED lamp types (including globe, decorative and downlights). This characterization assumes that the LED lamp or fixture is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used[813].

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 LED lamp or fixture. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd).

Definition of Baseline Equipment

The baseline condition is assumed to be an incandescent/halogen lamp for all lamp types.

The baseline for the early replacement measure is the existing bulb being replaced.

Deemed Lifetime of Efficient Equipment

While LED rated lives are often 15,000 – 50,000 hours, all installations are assumed to be 10 years[814] except for recessed downlight and track lights at 15 years[815]

For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFL's, the remaining life is 3,333 hours[816].

Deemed Measure Cost

The price of LED lamps is falling quickly. Where possible, the actual cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following[817]:

Bulb Type	Year	Incandescent	LED	Incremental Cost
Recessed Downlight Luminaires	All	$4.00	$94.00	$90.00
Track Lights	All	$4.00	$60.00	$56.00
Directional	2017	$3.53	$6.24	$2.71
	2018-2019		$5.18	$1.65
Decorative and Globe	2017	$1.60	$3.50	$1.90
	2018-2019	$1.74	$3.40	$1.66

[813] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112016.xls'.

[814] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

[815] Limited by persistence. NEEP EMV Emerging Technologies Research Report (December 2011)

[816] Representing a third of the expected lamp lifetime.

[817] Baseline and LED lamp costs for both directional and decorative and globe are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis. Recessed downlight and track light costs are based on VEIC review of a year's worth of LED sales data through VEIC implemented programs and the retail cost averaged (see 2015 LED Sales Review.xls) and of price reports provided to Efficiency Vermont by a number of manufacturers and retailers. Baseline cost based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.

LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

COINCIDENCE FACTOR

Unlike standard lamps that could be installed in any room, certain types of specialty lamps are more likely to be found in specific rooms, which affects the coincident peak factor. Coincidence factors by bulb types are presented below[818]

Bulb Type	Peak CF
Three-way	0.078[819]
Dimmable	0.078[820]
Interior reflector (incl. dimmable)	0.091
Exterior reflector	0.273
Unknown reflector	0.094
Candelabra base and candle medium and intermediate base	0.121
Bug light	0.273
Post light (>100W)	0.273
Daylight	0.081
Plant light	0.081
Globe	0.075
Vibration or shatterproof	0.081
Standard Spiral >=2601 lumens, Residential, Multi-family in unit	0.071
Standard spirals >= 2601 lumens, unknown	0.081
Standard spirals >= 2601 lumens, exterior	0.273
Specialty - Generic	0.081

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

ΔkWh = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the table below for default values.

EISA exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Standard Spirals >=2601	2601	2999	150

818 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
819 Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
820 Ibid

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
	3000	5279	200
	5280	6209	300
3-Way	250	449	25
	450	799	40
	800	1099	60
	1100	1599	75
	1600	1999	100
	2000	2549	125
	2550	2999	150
Globe (medium and intermediate bases less than 750 lumens)	90	179	10
	180	249	15
	250	349	25
	350	749	40
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10
	90	149	15
	150	299	25
	300	749	40
Globe (candelabra bases less than 1050 lumens)	90	179	10
	180	249	15
	250	349	25
	350	499	40
	500	1049	60
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10
	90	149	15
	150	299	25
	300	499	40
	500	1049	60

Directional Lamps -

For Directional R, BR, and ER lamp types[821]:

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$
R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40
	473	524	45
	525	714	50
	715	937	65
	938	1259	75
	1260	1399	90
	1400	1739	100
	1740	2174	120
	2175	2624	150
	2625	2999	175
	3000	4500	200
	400	449	40

[821] From pg 11 of the Energy Star Specification for lamps v1.1

Bulb Type	Lower Lumen Range	Upper Lumen Range	$Watts_{Base}$
***R, BR, and ER with medium screw bases w/ diameter <=2.25"**	450	499	45
	500	649	50
	650	1199	65
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40
	450	719	45
***All reflector lamps below lumen ranges specified above**	200	299	20
	300	399	30

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[822] If CBCP and beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[823]

$$\mathrm{Wattsbase} =$$

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

Diameter	Permitted Wattages
16	20, 35, 40, 45, 50, 60, 75
20	50
30S	40, 45, 50, 60, 75
30L	50, 75
38	40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250

[822] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

[823] The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

EISA non-exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	Incandescent Equivalent Post-EISA 2007 (WattsBase)
Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	310	749	29
	750	1049	43
	1050	1489	53
	1490	2600	72

$Watts_{EE}$ = Actual wattage of LED purchased / installed.

ISR = In Service Rate or the percentage of units rebated that get installed

Program	Bulb Type	Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Retail (Time of Sale)	Recessed downlight luminaries and Track Lights	100%[824]			
	All other lamps	93.5%[825]	2.4%	2.1%	98.0%[826]
Direct Install	All lamps	96.9%[827]			

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[828]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[829]:

824 NEEP EMV Emerging Technologies Research Report (December 2011)

825 1st year in service rate is based upon analysis of ComEd PY7 and PY8 intercept data (see 'IL RES Lighting ISR_112016.xls' for more information).

826 The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

827 Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

828 Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

829 Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year [830]

Bulb Type	Annual hours of use (HOU)
Three-way	850
Dimmable	850
Interior reflector (incl. dimmable)	861
Exterior reflector	2475
Unknown reflector	891
Candelabra base and candle medium and intermediate base	1190
Bug light	2475
Post light (>100W)	2475
Daylight	847
Plant light	847
Globe	639
Vibration or shatterproof	847
Standard Spiral >2601 lumens, Residential, Multi Family in-unit	759
Standard Spiral >2601 lumens, unknown	847
Standard Spiral >2601 lumens, Exterior	2475
Specialty – Generic Interior	847
Specialty – Generic Exterior	2475

WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting

Bulb Location	WHFe
Interior single family or unknown location	1.06 [831]
Multi family in unit	1.04 [832]
Exterior or uncooled location	1.0

For example, a 13W PAR20 LED is installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium

[830] Hours of use by specialty bulb type calculated using the average hours of use in locations or rooms where each type of specialty bulb is most commonly found. Values for Reflector, Decorative and Globe are taken directly from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. All other hours have been updated based on the room specific hours of use from the PY5/PY6 logger study.

[831] The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[832] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

screw base, diameter >2.5", installed in single family interior location:

ΔkWh = ((45 - 13) / 1000) * 0.935 * 861 * 1.06

= 27.3 kWh

Mid Life Baseline Adjustment

For non-exempt lamps, an appropriate baseline adjustment should be included to account for the 2020 EISA backstop provision making replacement baseline lamps meet 45 lumens/watt. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

Note for early replacement measures an additional baseline shift accounting for the replacement of the existing unit with a new baseline lamp should be accounted for.

HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[833] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / ηHeat

Where:

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

= 49%[834] for interior or unknown location

= 0% for exterior location

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [835]:

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[836]	N/A	N/A	1.28

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

834 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

835 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

836 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

For example, a 13W PAR20 LED is installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5",installed in single family interior location with a 2016 heat pump:

ΔkWh = - ((45 - 13) / 1000) * 0.935 * 861 * 0.49) / 2.04

= - 6.19 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

Bulb Location	WHFd
Interior single family or unknown location	1.11[837]
Multi family in unit	1.07[838]
Exterior or uncooled location	1.0

CF = Summer Peak Coincidence Factor for measure, see above for values. [839]

Bulb Type	Peak CF
Three-way	0.078[840]
Dimmable	0.078[841]
Interior reflector (incl. dimmable)	0.091
Exterior reflector	0.273
Unknown reflector	0.094
Candelabra base and candle medium and intermediate base	0.121
Bug light	0.273
Post light (>100W)	0.273
Daylight	0.081
Plant light	0.081
Globe	0.075
Vibration or shatterproof	0.081
Standard Spiral >=2601 lumens, Residential, Multi-family in unit	0.071
Standard spirals >= 2601 lumens, unknown	0.081
Standard spirals >= 2601 lumens, exterior	0.273
Specialty - Generic	0.081

Other factors as defined above

837 The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

838 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

839 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

840 Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

841 Ibid

For example, a 13W PAR20 LED is installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5", installed in single family interior location:

$$\Delta kW = ((45 - 13) / 1000) * 0.935 * 1.11 * 0.091$$

$$= 0.0030 \text{ kW}$$

NATURAL GAS SAVINGS

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

$$\Delta therms = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / \eta Heat$$

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% [842] for interior or unknown location

= 0% for exterior location

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [843]

Other factors as defined above

For example, a 13W PAR20 LED is installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5", installed in single family interior location with gas heating at 70% total efficiency:

$$\Delta therms = - (((45 - 13) / 1000) * 0.935 * 861 * 0.49 * 0.03412) / 0.70$$

$$= - 0.62 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

For those bulbs types exempt from EISA (except for reflectors) the following O&M assumptions should be used: Life of the baseline bulb is assumed to be 1.32 year[844]; baseline replacement cost is assumed to be $4.0.

For reflectors the life of the baseline bulb and the cost of its replacement is presented in the following table:

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[842] Average result from REMRate modeling of several different configurations and IL locations of homes

[843] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[844] Assuming 1000 hour rated life for incandescent bulb: 1000/759 = 1.32

Lamp Type	Baseline Lamp Life (hours)	Baseline Life (Single Family and in unit Multifamily - 1010 hours)	Baseline Replacement Cost
PAR20, PAR30, PAR38 screw-in lamps	2000	2.0	$4.00
MR16/PAR16 pin-based lamps	2000	2.0	$3.00
Recessed downlight luminaries	2000	2.0	$4.00
Track lights	2000	2.0	$4.00

For non-exempt EISA bulb types defined above, in order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

Bulb replacement costs assumed in the O&M calculations are provided below[845].

	EISA Compliant Incandescent /Halogen (Decorative/Globe)	Specialty CFL
2017	$1.74	N/A
2018	$1.74	N/A
2019	$1.74	N/A
2020 & after	N/A	$3.40[846]

Installation Location	Omnidirectional LED Measure Hours	Hours of Use per year [847]	Measure Life in Years (capped at 10)
Interior and Unknown	15,000	847	10
Exterior	15,000	2475	6.1

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below[848].

Location	EISA Compliant Bulb Type	NPV of replacement costs for period			Levelized annual replacement cost savings		
		2018	2019	2020	2018	2019	2020
Interior and Unknown	Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	$2.86	$2.86	$2.86	$0.29	$0.29	$0.29
Exterior		$5.96	$5.96	$5.96	$0.61	$0.61	$0.61

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

845 Baseline costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
846 Assumed consistent with LED cost.
847 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluations.
848 See "Specialty LED EISA compliant O&M Calc.xlsx" for calculation.

MEASURE CODE: RS-LTG-LEDD-V07-180101

REVIEW DEADLINE: 1/1/2020

5.5.7 LED Exit Signs

Description

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a MultiFamily building. Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

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

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

Definition of Efficient Equipment

The efficient equipment is assumed to be an exit sign illuminated by LEDs.

Definition of Baseline Equipment

The baseline equipment is assumed to be a fluorescent or incandescent model.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 16 years[849].

Deemed Measure Cost

The incremental cost for this measure is assumed to be $30[850].

Loadshape

Loadshape C53 - Flat

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 100%[851].

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * WHF_e$$

Where:

WattsBase = Actual wattage if known, if unknown assume the following:

[849] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.
[850] NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr.
[851] Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

Baseline Type	WattsBase
Incandescent	35W[852]
Fluorescent	11W[853]
Unknown (e.g. time of sale)	11W

WattsEE = Actual wattage if known, if unknown assume 2W[854]

HOURS = Annual operating hours

= 8766

WHF_e = Waste heat factor for energy; accounts for cooling savings from efficient lighting.

= 1.04[855] for multi family buildings

Default if replacing incandescent fixture

ΔkWH = (35 – 2)/1000 * 8766 * 1.04

= 301 kWh

Default if replacing fluorescent fixture

ΔkWH = (11 – 2)/1000 * 8766 * 1.04

= 82 kWh

HEATING PENALTY

If electric heated building (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[856] = - (((WattsBase - WattsEE) / 1000) * Hours * HF) / ηHeat

Where:

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

= 49%[857]

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [858]:

[852] Based on review of available product.
[853] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010
[854] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010
[855] The value is estimated at 1.04 (calculated as 1 + (0.45*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 3.1 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)
[856] Negative value because this is an increase in heating consumption due to the efficient lighting.
[857] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.
[858] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[859]	N/A	N/A	1.28

For example, a 2.0COP (including duct loss) Heat Pump heated building:

If incandescent fixture: ΔkWH = -((35 – 2)/1000 * 8766 * 0.49) / 2

= -71 kWh

If fluorescent fixture ΔkWH = -((11 – 2)/1000 * 8766 * 0.49) / 2

= -19 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((WattsBase - WattsEE) / 1000) * WHF_d * CF$$

Where:

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. The cooling savings are only added to the summer peak savings.

=1.07[860] for multi family buildings

CF = Summer Peak Coincidence Factor for measure

= 1.0

Default if incandescent fixture

ΔkW = (35 – 2)/1000 * 1.07 * 1.0

= 0.035 kW

Default if fluorescent fixture

ΔkW = (11 – 2)/1000 * 1.07 * 1.0

= 0.0096 kW

NATURAL GAS SAVINGS

Heating penalty if Natural Gas heated building, or if heating fuel is unknown.

$$\Delta therms = - (((WattsBase - WattsEE) / 1000) * Hours * HF * 0.03412) / \eta Heat$$

losses. Defaults provided assume 15% duct loss for heat pumps.

859 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

860 The value is estimated at 1.11 (calculated as 1 + (0.45 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% [861]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [862]

Other factors as defined above

Default if incandescent fixture

Δtherms = - (((35 - 2) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -6.9 therms

Default if fluorescent fixture

Δtherms = - (((11 - 2) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -1.9 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

	Baseline Measures	
Component	Cost	Life (yrs)
Lamp	$7.00[863]	1.37 years[864]

MEASURE CODE: RS-LTG-LEDE-V02-180101

REVIEW DEADLINE: 1/1/2019

[861] Average result from REMRate modeling of several different configurations and IL locations of homes

[862] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[863] Consistent with assumption for a Standard CFL bulb with an estimated labor cost of $4.50 (assuming $18/hour and a task time of 15 minutes).

[864] Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.

5.5.8 LED Screw Based Omnidirectional Bulbs

Description

This characterization provides savings assumptions for LED Screw Based Omnidirectional (e.g. A-Type lamps) lamps within the residential and multifamily sectors. This characterization assumes that the LED lamp or fixture is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used[865].

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

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

Definition of Efficient Equipment

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd).

Definition of Baseline Equipment

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EIAS) will require all general-purpose light bulbs between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards apply; in 2013 the 75 w lamp standards will apply, followed by restrictions on the 60 w and 40 w lamps in 2014. Since measures installed under this TRM all occur after 2014, baseline equipment are the values after EISA. These are shown in the baseline table below.

The baseline for the early replacement measure is the existing bulb being replaced.

Deemed Lifetime of Efficient Equipment

The deemed measure life is 6.1 years[866] for exterior application. For all other applications, lifetimes are capped at 10 years[867].

For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFL's, the remaining life is 3,333 hours[868].

Deemed Measure Cost

The price of LED lamps is falling quickly. Where possible, the actual LED lamp cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following[869]:

Year	EISA Compliant Halogen	LED-A	Incremental Cost
2017	$1.25	$3.21	$1.96
2018		$3.21	$1.96

[865] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112016.xls'.
[866] ENERGY STAR v2.0 requires omnidirectional LED bulbs to be rated for at least 15,000 hours. 15000/2475 (exterior hours of use) = 6.1 years.
[867] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.
[868] Representing a third of the expected lamp lifetime.
[869] Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

Year	EISA Compliant Halogen	LED-A	Incremental Cost
2019		$3.11	$1.86

LOADSHAPE

Loadshape R06 – Residential Indoor Lighting

Loadshape R07 – Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1% for Residential and in-unit Multi Family bulbs, 27.3% for exterior bulbs and 8.1% for unknown[870].

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WHF_e$$

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the "LED New and Baseline Assumptions" table for default values.

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

LED New and Baseline Assumptions Table

Minimum Lumens	Maximum Lumens	Lumens used to calculate LED Wattage (midpoint)	LED Wattage [871] (WattsEE)	Baseline 2014-2019 (WattsBase)	Delta Watts 2014-2019 (WattsEE)	Baseline Post EISA 2020 requirement[872] (WattsBase)	Delta Watts Post 2020 (WattsEE)
5280	6209	5745	72.9	300.0	227.1	300.0	227.1
3000	5279	4140	52.5	200.0	147.5	200.0	147.5
2601	2999	2800	35.5	150.0	114.5	150.0	114.5
1490	2600	2045	26.0	72.0	46.0	45.4	19.5
1050	1489	1270	16.1	53.0	36.9	28.2	12.1
750	1049	900	11.4	43.0	31.6	20.0	8.6
310	749	530	6.7	29.0	22.3	11.8	5.0
250	309	280	3.5	25.0	21.5	25.0	21.5

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

[870] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[871] Based on ENERGY STAR V2.0 specs – for omnidirectional <90CRI: 80 lm/W and for omnidirectional >=90 CRI: 70 lm/W. To weight these two criteria, the ENERGY STAR qualified list was reviewed and found to contain 87.8% lamps <90CRI and 12.2% >=90CRI.

[872] Calculated as 45lm/W for all EISA non-exempt bulbs.

Program		Weighted Average 1st year In Service Rate (ISR)	2nd year Installations	3rd year Installations	Final Lifetime In Service Rate
Retail (Time of Sale)		89.9%[873]	4.3%	3.7%	98.0%[874]
Direct Install		96.9%[875]			
Efficiency Kits[876]	CFL Distribution[877]	59%	13%	11%	83%
	School Kits[878]	61%	13%	11%	86%
	Direct Mail Kits[879]	66%	14%	12%	93%

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[880]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[881]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

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[873] 1st year in service rate is based upon analysis of ComEd PY7 and PY8 and Ameren PY8 intercept data (see 'IL RES Lighting ISR_112016.xls' for more information).

[874] The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[875] Based upon Standard CFL assumption in the absence of better data, and is based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

[876] In Service Rates provided are for the bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provide may be used.

[877] Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

[878] Kits provided free to students through school, with education program. Consistent with Standard CFL assumptions.

[879] Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

[880] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[881] Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

Installation Location	Hours[882]
Residential and in-unit Multi Family	759
Exterior	2475
Unknown	847

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

Bulb Location	WHFe
Interior single family or unknown location	1.06 [883]
Multi family in unit	1.04 [884]
Exterior or uncooled location	1.0

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 over time (except for <300 and 2600+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift.

For example, for 60W equivalent bulbs installed in 2018, the full savings (as calculated above in the Algorithm) should be claimed for the first three 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.

Minimum Lumens	Maximum Lumens	LED Wattage (WattsEE)	Delta Watts 2014-2019 (WattsEE)	Delta Watts Post 2020 (WattsEE)	Mid Life adjustment (made from 01/2021) to first year savings
1490	2600	26.0	46.0	19.5	42.3%
1050	1489	16.1	36.9	12.1	32.8%
750	1049	11.4	31.6	8.6	27.1%
310	749	6.7	22.3	5.0	22.6%

882 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
883 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)
884 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

For example, an 8W LED lamp, 450 lumens, is installed in the interior of a home. The customer purchased the lamp through an upstream program:

$$\Delta kWH = ((29-6.7 /1000) * 847 * 1.06 * 0.899$$

$$= 18.0 \text{ kWh}$$

This value should be claimed for three years, i.e. 2018-2020, but from 2021 until the end of the measure life for that same bulb, savings should be reduced to (18.0 * 0.226 =) 4.1 kWh for the remainder of the measure life. Note these adjustments should be applied to kW and fuel impacts as well.

Note for early replacement measures an additional baseline shift accounting for the replacement of the existing unit with a new baseline lamp should be accounted for.

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

Using the example from above, for an 8W LED, 450 Lumens purchased for the interior of a residential homes through an upstream program.

$$\Delta kWH_{1st\ year\ installs} = ((29-6.7)/1000)*847*1.06*0.899$$

$$= 18.0 \text{ kWh}$$

$$\Delta kWH_{2nd\ year\ installs} = ((29-6.7)/1000)*847*1.06*0.043$$

$$= 0.9 \text{ kWh}$$

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

$$\Delta kWh^{885} = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / \eta Heat$$

Where:

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

= 49%[886] for interior or unknown location

= 0% for exterior or unheated location

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

[886] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[887]:

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate) = (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1.00
Unknown[888]	N/A	N/A	1.28

Using the same 8 W LED that is installed in home with 2.0 COP Heat Pump (including duct loss):

$\Delta kWh_{1st\ year}$ = - (((29-6.7) / 1000) * 0.899 * 759 * 0.49) / 2.0

= - 3.7 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

Bulb Location	WHFd
Interior single family or unknown location	1.11[889]
Multi family in unit	1.07[890]
Exterior or uncooled location	1.0

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF[891]
Interior single family or unknown location or Multi family in unit	7.1%

[887] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[888] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

[889] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[890] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[891] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluations.

Bulb Location	CF[891]
Exterior	27.3%
Unknown	8.1%

Other factors as defined above

For the same 8 W LED that is installed in a single family interior location, the demand savings are:

ΔkW = ((29-6.7) / 1000) * 0.899* 1.11 * 0.071

= 0.0016 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

NATURAL GAS SAVINGS

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

ΔTherms = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% [892] for interior or unknown location

= 0% for exterior location

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [893]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Bulb replacement costs assumed in the O&M calculations are provided below[894].

	Std Inc.	EISA Compliant Halogen	CFL	LED-A
2017	$0.43	$1.25	N/A	$3.21

[892] Average result from REMRate modeling of several different configurations and IL locations of homes

[893] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[894] Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

	Std Inc.	EISA Compliant Halogen	CFL	LED-A
2018	$0.43	$1.25	N/A	$3.21
2019	$0.43	$1.25	N/A	$3.11
2020 & after	$0.43	N/A	$2.45	$2.70

In order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

Installation Location	Omnidirectional LED Measure Hours	Hours of Use per year [895]	Measure Life in Years (capped at 10)
Residential and in-unit Multi Family	15,000	759	10
Exterior	15,000	2475	6.1
Unknown	15,000	847	10

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below[896]. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

Location	Lumen Level	NPV of replacement costs for period			Levelized annual replacement cost savings		
		2018	2019	2020	2018	2019	2020
Residential and in-unit Multi Family	Lumens <310 or >2600 (non-EISA compliant)	$2.86	$2.86	$2.86	$0.29	$0.29	$0.29
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$3.14	$2.38	$1.63	$0.32	$0.24	$0.17
Exterior	Lumens <310 or >2600 (non-EISA compliant)	$5.96	$5.96	$5.96	$0.61	$0.61	$0.61
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$9.79	$7.34	$4.87	$1.00	$0.75	$0.50
Unknown	Lumens <310 or >2600 (non-EISA compliant)	$3.19	$3.19	$3.19	$0.33	$0.33	$0.33
	Lumens ≥ 310 and ≤ 2600 (EISA compliant)	$3.50	$2.66	$1.82	$0.36	$0.27	$0.19

Note incandescent lamps in lumen range <310 and >2600 are exempt from EISA. For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[897] The replacement cycle is based on the location of the lamp and varies based on the hours of use for that location. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement.

895 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluations.

896 See "LED TRM Examples_012017.xls" for calculation.

897 The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.

MEASURE CODE: RS-LTG-LEDA-V05-180101

REVIEW DEADLINE: 1/1/2020

5.6 Shell End Use

5.6.1 Air Sealing

DESCRIPTION

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. Leaks are detected and leakage rates measured with the assistance of a blower-door. The algorithm for this measure can be used when the program implementation does not allow for more detailed forecasting through the use of residential modeling software.

Prescriptive savings are provided for use only where a blower door test is not possible (for example in large multi family buildings).

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

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

DEFINITION OF EFFICIENT EQUIPMENT

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be performed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

DEFINITION OF BASELINE EQUIPMENT

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[898]

DEEMED MEASURE COST

The actual capital cost for this measure should be used in screening.

LOADSHAPE

Loadshape R08 - Residential Cooling
Loadshape R09 - Residential Electric Space Heat
Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

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

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

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

= 68%[899]

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

= 72%%[900]

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

= 46.6%[901]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Blower Door Test

Preferred methodology unless blower door testing is not possible.

ΔkWh = ΔkWh_cooling + ΔkWh_heating

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

= [(((CFM50_existing - CFM50_new)/N_cool) * 60 * 24 * CDD * DUA * 0.018) / (1000 * ηCool)] * LM

CFM50_existing = Infiltration at 50 Pascals as measured by blower door before air sealing.

= Actual

CFM50_new = Infiltration at 50 Pascals as measured by blower door after air sealing.

= Actual

N_cool = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

=Dependent on location and number of stories:[902]

Climate Zone (City based upon)	N_cool (by # of stories)			
	1	1.5	2	3
1 (Rockford)	39.5	35.0	32.1	28.4
2 (Chicago)	38.9	34.4	31.6	28.0
3 (Springfield)	41.2	36.5	33.4	29.6
4 (St Louis, MO)	40.4	35.8	32.9	29.1
5 (Paducah, KY)	43.6	38.6	35.4	31.3

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

900 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

902 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".

60 * 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

= Dependent on location[903]:

Climate Zone (City based upon)	CDD 65
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [904]

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[905]:

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[906]

Climate Zone (City based upon)	LM
1 (Rockford)	3.3
2 (Chicago)	3.2
3 (Springfield)	3.7
4 (St Louis, MO)	3.6
5 (Paducah, KY)	3.7

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to

[903] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.
[904] 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.
[905] 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.
[906] Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc".

air sealing

= (((CFM50_existing - CFM50_new)/N_heat) * 60 * 24 * HDD * 0.018) / (ηHeat * 3,412)

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone, building height and exposure level:[907]

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
1 (Rockford)	23.8	21.1	19.3	17.1
2 (Chicago)	23.9	21.1	19.4	17.2
3 (Springfield)	24.2	21.5	19.7	17.4
4 (St Louis, MO)	25.4	22.5	20.7	18.3
5 (Paducah, KY)	27.8	24.6	22.6	20.0

HDD = Heating Degree Days

= Dependent on location:[908]

Climate Zone (City based upon)	HDD 60
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below[909]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

3412 = Converts Btu to kWh

907 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".

908 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.

909 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.

For example, a 2 story single family home in Chicago with 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), has pre and post blower door test results of 3,400 and 2,250:

ΔkWh = ΔkWh_cooling + ΔkWh_heating

= [((((3,400 – 2,250) / 31.6) * 60 * 24 * 842 * 0.75 * 0.018) / (1000 * 10.5)) * 3.2] + [((3,400 – 2,250) / 19.4)) * 60 * 24 * 5113 * 0.018 / (1.92 * 3,412)]

= 182 + 1199

= 1,381 kWh

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%[910]

29.3 = kWh per therm

For example, a well shielded, 2 story single family home in Chicago with a gas furnace with system efficiency of 70%, has pre and post blower door test results of 3,400 and 2,250 (see therm calculation in Natural Gas Savings section:

ΔkWh = 109.1 * 0.0314 * 29.3

= 100 kWh

Methodology 2: Prescriptive Infiltration Reduction Measures[911]

Savings shall only be calculated via Methodology 2 if a blower door test is not feasible. Cooling savings are not quantified using Methodology 2.

ΔkWh_heating = $(\Delta kWh_{gasket} * n_{gasket} + \Delta kWh_{sweep} * n_{sweep} + \Delta kWh_{sealing} * lf_{sealing} + \Delta kWh_{WX} * lf_{WX}) * ADJ_{RxAirsealing}$

Where:

ΔkWh_{gasket} = Annual kWh savings from installation of air sealing gasket on an electric outlet

Climate Zone (City based upon)	ΔkWh_{gasket} / gasket	
	Electric Resistance	Heat Pump
1 (Rockford)	10.5	5.3
2 (Chicago)	10.2	5.1
3 (Springfield)	8.8	4.4

910 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.

911 Prescriptive savings are based upon "Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)." Middletown, CT: KEMA, 2010. Accessed July 30, 2015, (http://www.energizect.com/sites/default/files/Final%20WRAP%20%20Helps%20Report.pdf) and adjusted for relative HDD of Bridgeport/Hartford CT with the IL climate zones. See 'Rx Airsealing HDD adjustment.xls' for more information.

Climate Zone (City based upon)	ΔkWh_{gasket} / gasket	
	Electric Resistance	Heat Pump
4 (Belleville)	7.0	3.5
5 (Marion)	7.2	3.6

n_{gasket} = Number of gaskets installed

ΔkWh_{sweep} =Annual kWh savings from installation of door sweep

Climate Zone (City based upon)	ΔkWh_{sweep} / sweep	
	Electric Resistance	Heat Pump
1 (Rockford)	202.4	101.2
2 (Chicago)	195.3	97.6
3 (Springfield)	169.3	84.7
4 (Belleville)	134.9	67.5
5 (Marion)	137.9	68.9

n_{sweep} = Number of sweeps installed

$\Delta kWh_{sealing}$ = Annual kWh savings from foot of caulking, sealing, or polyethlylene tape

Climate Zone (City based upon)	$\Delta kWh_{sealing}$ / ft	
	Electric Resistance	Heat Pump
1 (Rockford)	11.6	5.8
2 (Chicago)	11.2	5.6
3 (Springfield)	9.7	4.8
4 (Belleville)	7.7	3.9
5 (Marion)	7.9	3.9

$lf_{sealing}$ = linear feet of caulking, sealing, or polyethylene tape

ΔkWh_{WX} = Annual kWh savings from window weatherstripping or door weatherstripping

Climate Zone (City based upon)	ΔkWh_{WX} / ft	
	Electric Resistance	Heat Pump
1 (Rockford)	13.5	6.7
2 (Chicago)	13.0	6.5
3 (Springfield)	11.3	5.6
4 (Belleville)	9.0	4.5
5 (Marion)	9.2	4.6

lf_{WX} = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[912].

= 80%

[912] Though we do not have a specific evaluation to point to, modeled savings have often been found to overclaim. Further VEIC reviewed these deemed estimates and consider them to likely be a high estimate. As such an 80% adjustment is applied, and this could be further refined with future evaluations.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = (\Delta kWh\_cooling / FLH\_cooling) * CF$

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[913]:

Climate Zone (City based upon)	Single Family	Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820

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

= 68%[914]

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

= 72%%[915]

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

= 46.6%[916]

Other factors as defined above

For example, a well shielded, 2 story single family home in Chicago with 10.5 SEER central cooling and a heat pump with COP of 2.0, has pre and post blower door test results of 3,400 and 2,250:

ΔkW_{SSP} = 182 / 570 * 0.68

= 0.22 kW

ΔkW_{PJM} = 182 / 570 * 0.466

= 0.15 kW

NATURAL GAS SAVINGS

Methodology 1: Blower Door Test

Preferred methodology unless blower door testing is not possible.

If Natural Gas heating:

913 Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH.

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

915 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

ΔTherms = (((CFM50_existing - CFM50_new)/N_heat) * 60 * 24 * HDD * 0.018) / (ηHeat * 100,000)

Where:

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone and building height[917]

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
1 (Rockford)	23.8	21.1	19.3	17.1
2 (Chicago)	23.9	21.1	19.4	17.2
3 (Springfield)	24.2	21.5	19.7	17.4
4 (St Louis, MO)	25.4	22.5	20.7	18.3
5 (Paducah, KY)	27.8	24.6	22.6	20.0

HDD = Heating Degree Days

= dependent on location[918]:

Climate Zone (City based upon)	HDD 60
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[919]. If not available use 72%[920].

Other factors as defined above

For example, a 2 story single family home in Chicago with a gas furnace with system efficiency of 70%, has pre and post blower door test results of 3,400 and 2,250:

ΔTherms = ((3,400 – 2,250)/19.4) * 60 * 24 * 5113 * 0.018) / (0.72 * 100,000)

= 109.1 therms

[917] 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".

[918] 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..

[919] 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.

[920] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

Methodology 2: Prescriptive Infiltration Reduction Measures[921]

Savings shall only be calculated via Methodology 2 if a blower door test is not feasible.

$\Delta therms = (\Delta therms_{gasket} * n_{gasket} + \Delta therms_{sweep} * n_{sweep} + \Delta therms_{sealing} * lf_{sealing} + \Delta therms_{WX} * lf_{WX}) * ADJ_{RxAirsealing}$

Where:

$\Delta therms_{gasket}$ = Annual therm savings from installation of air sealing gasket on an electric outlet

Climate Zone (City based upon)	$\Delta therms_{gasket}$ / gasket Gas Heat
1 (Rockford)	0.49
2 (Chicago)	0.47
3 (Springfield)	0.41
4 (Belleville)	0.33
5 (Marion)	0.33

n_{gasket} = Number of gaskets installed

$\Delta therms_{sweep}$ = Annual therm savings from installation of door sweep

Climate Zone (City based upon)	$\Delta therms_{sweep}$ / sweep Gas Heat
1 (Rockford)	9.46
2 (Chicago)	9.13
3 (Springfield)	7.92
4 (Belleville)	6.31
5 (Marion)	6.45

n_{sweep} = Number of sweeps installed

$\Delta therms_{sealing}$ = Annual therm savings from foot of caulking, sealing, or polyethlylene tape

Climate Zone (City based upon)	$\Delta therms_{sealing}$ / ft Gas Heat
1 (Rockford)	0.54
2 (Chicago)	0.52
3 (Springfield)	0.45
4 (Belleville)	0.36
5 (Marion)	0.37

$lf_{sealing}$ = linear feet of caulking, sealing, or polyethylene tape

$\Delta therms_{WX}$ = Annual therm savings from window weatherstripping or door weatherstripping

Climate Zone (City based upon)	$\Delta therms_{sx}$ / ft Gas Heat
1 (Rockford)	0.63

[921] Prescriptive savings are based upon "Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)." Middletown, CT: KEMA, 2010. Accessed July 30, 2015, (http://www.energizect.com/sites/default/files/Final%20WRAP%20%20Helps%20Report.pdf) and adjusted for relative HDD of Bridgeport/Hartford CT with the IL climate zones. See 'Rx Airsealing HDD adjustment.xls' for more information.

Climate Zone (City based upon)	$\Delta therms_{sx}$ / ft Gas Heat
2 (Chicago)	0.61
3 (Springfield)	0.53
4 (Belleville)	0.42
5 (Marion)	0.43

lf_{WX} = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[922].

= 80%

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AIRS-V06-180101

REVIEW DEADLINE: 1/1/2020

[922] Though we do not have a specific evaluation to point to, modeled savings have often been found to overclaim. Further VEIC reviewed these deemed estimates and consider them to likely be a high estimate. As such an 80% adjustment is applied, and this could be further refined with future evaluations.

5.6.2 Basement Sidewall Insulation

DESCRIPTION

Insulation is added to a basement or crawl space. Insulation added above ground in conditioned space is modeled the same as wall insulation. Below ground insulation is adjusted with an approximation of the thermal resistance of the ground. Insulation in unconditioned spaces is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no basement wall or ceiling insulation.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[923]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

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

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

= 68%[924]

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

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

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

= 72%%[925]

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

= 46.6%[926]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool))) * $ADJ_{BasementCool}$

R_added = R-value of additional spray foam, rigid foam, or cavity insulation.

R_old_AG = R-value value of foundation wall above grade.

= Actual, if unknown assume 1.0[927]

L_basement_wall_total = Length of basement wall around the entire insulated perimeter (ft)

H_basement_wall_AG = Height of insulated basement wall above grade (ft)

Framing_factor = Adjustment to account for area of framing when cavity insulation is used

= 0% if Spray Foam or External Rigid Foam

= 25% if studs and cavity insulation[928]

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:[929]

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[925] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

[927] 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

[928] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

[929] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

Climate Zone (City based upon)	Conditioned CDD 65	Unconditioned CDD 65[930]
1 (Rockford)	820	263
2 (Chicago)	842	281
3 (Springfield)	1,108	436
4 (Belleville)	1,570	538
5 (Marion)	1,370	570
Weighted Average[931]	947	325

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [932]

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:[933]

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

$ADJ_{BasementCool}$ = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[934].

= 80%

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= ([((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) + ((1/(R_old_BG - 1/(R_added+R_old_BG)) * L_basement_wall_total * (H_basement_wall_total - H_basement_wall_AG) * (1-Framing_factor))] * 24 * HDD) / (3,412 * ηHeat)) * $ADJ_{BasementHeat}$

Where

R_old_BG = R-value value of foundation wall below grade (including thermal resistance of

930 Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F.

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

932 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.

933 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.

934 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.

the earth) [935]

= dependent on depth of foundation (H_basement_wall_total – H_basement_wall_AG):

= Actual R-value of wall plus average earth R-value by depth in table below

Below Grade R-value									
Depth below grade (ft)	0	1	2	3	4	5	6	7	8
Earth R-value (°F-ft²-h/Btu)	2.44	4.50	6.30	8.40	10.44	12.66	14.49	17.00	20.00
Average Earth R-value (°F-ft2-h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69
Total BG R-value (earth + R-1.0 foundation) default	3.44	4.47	5.41	6.41	7.42	8.46	9.46	10.53	11.69

H_basement_wall_total = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:[936]

Climate Zone (City based upon)	Conditioned HDD 60	Unconditioned HDD 50
1 (Rockford)	5,352	3,322
2 (Chicago)	5,113	3,079
3 (Springfield)	4,379	2,550
4 (Belleville)	3,378	1,789
5 (Marion)	3,438	1,796
Weighted Average[937]	4,860	2,895

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[938]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	After 2006 - 2014	7.7	1.92

[935] Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

[936] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F for a conditioned basement and 50°F for an unconditioned basement), consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

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

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

$ADJ_{BasementHeat}$ = Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[939].

= 60%

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= [((((1/2.25 - 1/(13 + 2.25))*(20+25+20+25) * 3 * (1 - 0)) * 24 * 281 * 0.75)/(1000 * 10.5)) * 0.8] + [((((((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0)) + ((1 / (2.25 + 6.42) – 1 / (13 + 2.25 + 6.42)) * (20+25+20+25) * 4 * (1-0))) * 24 * 3079) / (3412 * 1.92)) * 0.6]

= (39.4 + 860.9)

= 900.3 kWh

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%[940]

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section :

= 78.3 * 0.0314 * 29.3

= 72.0 kWh

SUMMER COINCIDENT PEAK DEMAND

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

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939 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

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

= dependent on location[941]:

Climate Zone (City based upon)	Single Family	Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820
Weighted Average[942]	629	564

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

= 68%[943]

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

= 72%%[944]

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

= 46.6%[945]

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

ΔkW_{SSP} = 39.4 / 570 * 0.68

= 0.047 kW

ΔkW_{PJM} = 39.4 / 570 * 0.466

= 0.032 kW

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms = [((([((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor) + (1/(R_old_BG - 1/(R_added+R_old_BG)) * L_basement_wall_total * (H_basement_wall_total - H_basement_wall_AG) * (1-Framing_factor)] * 24 * HDD) / (ηHeat * 100,067)] * $ADJ_{BasementHeat}$

ηHeat = Efficiency of heating system

[941] Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd%20EPY2%20Evaluation%20Reports/ComEd_Central_AC_Efficiency_Services_PY2_Evaluation_Report_Final.pdf, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

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

[944] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

= Equipment efficiency * distribution efficiency

= Actual. If unknown assume 72%[946]

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 72% efficient furnace: = ((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0) + (1/8.67 - 1/(13 + 8.67)) * (20+25+20+25) * 4 * (1 - 0)) * 24 * 3079) / (0.72 * 100,067) * 0.60 = 78.3 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-BINS-V08-180101

REVIEW DEADLINE: 1/1/2020

[946] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

5.6.3 Floor Insulation Above Crawlspace

DESCRIPTION

Insulation is added to the floor above a vented crawl space that does not contain pipes or HVAC equipment. If there are pipes, HVAC, or a basement, it is desirable to keep them within the conditioned space by insulating the crawl space walls and ground. Insulating the floor separates the conditioned space above from the space below the floor, and is only acceptable when there is nothing underneath that could freeze or would operate less efficiently in an environment resembling the outdoors. Even in the case of an empty, unvented crawl space, it is still considered best practice to seal and insulate the crawl space perimeter rather than the floor. Not only is there generally less area to insulate this way, but there are also moisture control benefits. There is a "Basement Insulation" measure for perimeter sealing and insulation. This measure assumes the insulation is installed above an unvented crawl space and should not be used in other situations.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no insulation on any surface surrounding a crawl space.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[947]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape R08 - Residential Cooling
Loadshape R09 - Residential Electric Space Heat
Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

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

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

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

= 68%[948]

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

= 72%%[949]

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

= 46.6%[950]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old - 1/(R_added+R_old)) * Area * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool))) * $ADJ_{FloorCool}$

R_old = R-value value of floor before insulation, assuming 3/4" plywood subfloor and carpet with pad

= Actual. If unknown assume 3.96 [951]

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% [952]

24 = Converts hours to days

CDD = Cooling Degree Days

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

[949] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

[951] 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

[952] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

Climate Zone (City based upon)	Unconditioned CDD[953]
1 (Rockford)	263
2 (Chicago)	281
3 (Springfield)	436
4 (Belleville)	538
5 (Marion)	570
Weighted Average[954]	325

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [955]

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:[956]

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

$ADJ_{FloorCool}$ = Adjustment for cooling savings from floor to account for prescriptive engineering algorithms overclaiming savings[957].

= 80%

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= ((((1/R_old - 1/(R_added + R_old)) * Area * (1-Framing_factor) * 24 * HDD)/ (3,412 * ηHeat)) * $ADJ_{FloorHeat}$

HDD = Heating Degree Days:[958]

953 Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F.
954 Weighted based on number of occupied residential housing units in each zone.
955 Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.
956 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.
957 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.
958 National Climatic Data Center, Heating Degree Days with a base temp of 50°F to account for lower impact of unconditioned space on heating system. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

Climate Zone (City based upon)	Unconditioned HDD
1 (Rockford)	3,322
2 (Chicago)	3,079
3 (Springfield)	2,550
4 (Belleville)	1,789
5 (Marion)	1,796
Weighted Average[959]	2,895

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[960]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

$ADJ_{FloorHeat}$ = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings[961].

= 60%

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= ((((1/3.96 -1/(30+3.96))*(20*25)*(1-0.12)* 24 * 281*0.75)/(1000*10.5)) * 0.8 + (((1/3.96 - 1/(30+3.96))*(20*25)*(1-0.15) * 24 * 3079)/(3412*1.92)) * 0.6)

= (37.8 + 641.7)

= 679.5 kWh

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

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

[960] 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.

[961] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

= 3.14%[962]

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section):

ΔkWh = 60.4 * 0.0314 * 29.3

= 55.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location:[963]

Climate Zone (City based upon)	Single Family	Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820
Weighted Average[964]	629	564

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

= 68%[965]

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

= 72%%[966]

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

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962 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.

963 Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

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

966 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

= 46.6%[967]

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

ΔkW_{SSP} = 37.8 / 570 * 0.68

= 0.045 kW

ΔkW_{SSP} = 37.8 / 570 * 0.466

= 0.031 kW

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms = (1/R_old - 1/(R_added+R_old)) * Area * (1-Framing_factor)) * 24 * HDD) / (100,000 * ηHeat) * $ADJ_{FloorHeat}$

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual. If unknown assume 72%[968]

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 72% efficient furnace:

ΔTherms = (1 / 3.96 – 1 /(30 + 3.96))*(20 * 25) * (1 - 0.12) * 24 * 3079) / (100,000 * 0.72) * 0.60

= 60.4 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-FINS-V08-180101

REVIEW DEADLINE: 1/1/2020

[967] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[968] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

5.6.4 Wall and Ceiling/Attic Insulation

Description

Insulation is added to wall cavities, and/or attic. This measure requires a member of the implementation staff evaluating the pre and post R-values and measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

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

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

Definition of Efficient Equipment

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities and little or no attic insulation.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 25 years.[969]

Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

Loadshape

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

Coincidence Factor

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

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

= 68%[970]

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

= 72%%[971]

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

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

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

[971] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

= 46.6%[972]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall) + (1/R_old - 1/R_attic) * A_attic * (1-Framing_factor_attic)) * 24 * CDD * DUA) / (1000 * ηCool)) * $ADJ_{WallAtticCool}$

R_wall = R-value of new wall assembly (including all layers between inside air and outside air).

R_attic = R-value of new attic assembly (including all layers between inside air and outside air).

R_old = R-value value of existing assemble and any existing insulation.

(Minimum of R-5 for uninsulated assemblies[973])

A_wall = Net area of insulated wall (ft^2)

A_attic = Total area of insulated ceiling/attic (ft^2)

Framing_factor_wall = Adjustment to account for area of framing

= 25%[974]

Framing_factor_attic = Adjustment to account for area of framing

= 7%[975]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[976]

Climate Zone (City based upon)	CDD 65
1 (Rockford)	820
2 (Chicago)	842

[972] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[973] 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).
[974] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1
[975] Ibid.
[976] National Climatic Data Center, Cooling Degree Days are based on a base temp of 65°F. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

Climate Zone (City based upon)	CDD 65
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370
Weighted Average[977]	947

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [978]

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:[979]

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

$ADJ_{WallAtticCool}$ = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[980].

= 80%

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) + (1/R_old - 1/R_attic) * A_attic * (1-Framing_factor_attic)) * 24 * HDD] / (ηHeat * 3412)) * $ADJ_{WallAtticHeat}$

HDD = Heating Degree Days

= Dependent on location:[981]

[977] Weighted based on number of occupied residential housing units in each zone.
[978] 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.
[979] 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.
[980] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.
[981] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

Climate Zone (City based upon)	HDD 60
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438
Weighted Average[982]	4,860

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[983]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

3412 = Converts Btu to kWh

$ADJ_{WallAtticHeat}$ = Adjustment for wall and attic insulation to account for prescriptive engineering algorithms overclaiming savings[984].

= 60%

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11 and 700 ft^2 of R-5 attic insulated to R-38, 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((((1/5 - 1/11) * 990 * (1-0.25)) + ((1/5 - 1/38) * 700 * (1-0.07))) * 842 * 0.75 * 24)/ (1000 * 10.5)) * 0.8) + ((((((1/5 - 1/11) * 990 * (1-0.25)) + ((1/5 - 1/38) * 700 * (1-0.07))) * 5113 * 24) / (1.92 * 3412)) * 0.6)

= 224 + 2181

= 2405 kWh

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

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

983 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.

984 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 60%.

= 3.14%[985]

29.3 = kWh per therm

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11 and 700 ft^2 of R-5 attic insulated to R-38, with a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section):

ΔkWh = 216.4 * 0.0314 * 29.3

= 199.1 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location as below:[986]

Climate Zone (City based upon)	Single Family	Multifamily
1 (Rockford)	512	467
2 (Chicago)	570	506
3 (Springfield)	730	663
4 (Belleville)	1,035	940
5 (Marion)	903	820
Weighted Average[987]	629	564

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

= 68%[988]

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

72%%[989]

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

= 46.6%[990]

985 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.

986 Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

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

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

989 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

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

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11 and 700 ft^2 of R-5 attic insulated to R-38, 10.5SEER Central AC and 2.26 COP Heat Pump:

ΔkW_{SSP} = 224 / 570 * 0.68

= 0.27 kW

ΔkW_{PJM} = 224 / 570 * 0.466

= 0.18 kW

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms = ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) + ((1/R_old - 1/R_attic) * A_attic * (1-Framing_factor_attic))) * 24 * HDD) / (ηHeat * 100,067 Btu/therm) * $ADJ_{WallAtticHeat}$

Where:

HDD = Heating Degree Days

= Dependent on location:[991]

Climate Zone (City based upon)	HDD 60
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438
Weighted Average[992]	4,860

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual.[993] If unknown assume 72%.[994]

Other factors as defined above

[991] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
[992] Weighted based on number of occupied residential housing units in each zone.
[993] 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.
[994] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

For example, a single family home in Chicago with 990 ft^2 of R-5 walls insulated to R-11 and 700 ft^2 of R-5 attic insulated to R-38, with a gas furnace with system efficiency of 66%:

ΔTherms = ((((1/5 - 1/11) * 990 * (1-0.25)) + ((1/5 - 1/38) * 700 * (1-0.07))) * 24 * 5113) / (0.66 * 100,067) * 0.60

= 216.4 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AINS-V07-180101

REVIEW DEADLINE: 1/1/2020

5.7 Miscellaneous

5.7.1 High Efficiency Pool Pumps

DESCRIPTION

Conventional residential outdoor pool pumps are single speed, often oversized, and run frequently at constant flow regardless of load. Single speed pool pumps require that the motor be sized for the task that requires the highest speed. As such, energy is wasted performing low speed tasks at high speed. Two speed and variable speed pool pumps reduce speed when less flow is required, such as when filtering is needed but not cleaning, and have timers that encourage programming for fewer on-hours. Variable speed pool pumps use advanced motor technologies to achieve efficiency ratings of 90% while the average single speed pump will have efficiency ratings between 30% and 70%[995]. This measure is the characterization of the purchasing and installing of an efficient two speed or variable speed residential pool pump motor in place of a standard single speed motor of equivalent horsepower.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is an ENERGY STAR two speed or variable speed residential pool pump for in-ground pools.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a single speed residential pool pump.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for a two speed or variable speed pool pump is 10 years[996].

DEEMED MEASURE COST

The incremental cost is estimated as $235 for a two speed motor and $549 for a variable speed motor[997].

LOADSHAPE

Loadshape R15 – Residential Pool Pumps

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.831[998].

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

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

[997] ENERGY STAR Pool Pump Calculator.

[998] Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS[999]

ΔkWh two speed = $(((Hrs/Day_{base} * GPM_{base} * 60)/EF_{base}) - (((Hrs/Day_{2spH} * GPM_{2spH} * 60)/EF_{2spH} + ((Hrs/Day_{2spL} * GPM_{2spL} * 60)/EF_{2spL}))))/1000 * Days$

ΔkWh variable speed = $(((Hrs/Day_{base} * GPM_{base} * 60)/EF_{base}) - (((Hrs/Day_{vsH} * GPM_{vsH} * 60)/EF_{vsH} + ((Hrs/Day_{vsL} * GPM_{vsL} * 60)/EF_{vsL}))))/1000 * Days$

Where:

Hrs/Day_{base} = run hours of single speed pump

= 11.4

GPM_{base} = flow of single speed pump (gal/min)

= 64.4

60 = minutes per hour

EF_{base} = Energy Factor of baseline single speed pump (gal/Wh)

= 2.1

Hrs/Day_{2spH} = run hours of two speed pump at high speed

= 2

GPM_{2spH} = flow of two speed pump at high speed (gal/min)

= 56

EF_{2spH} = Energy Factor of two speed pump at high speed (gal/Wh)

= 2.4

Hrs/Day_{2spL} = run hours of two speed pump at low speed

= 15.7

GPM_{2spL} = flow of two speed pump at low speed (gal/min)

= 31

EF_{2spL} = Energy Factor of two speed pump at high speed (gal/Wh)

= 5.4

Hrs/Day_{vsH} = run hours of variable speed pump at high speed

= 2

GPM_{vsH} = flow of variable speed pump at high speed (gal/min)

= 50

EF_{vsH} = Energy Factor of variable speed pump at high speed (gal/Wh)

[999] The methodology and all assumptions are sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.5 turnovers per day in the efficient case.

= 3.8

Hrs/Day_{vsL} = run hours of variable speed pump at low speed

= 16

GPM_{vsL} = flow of variable speed pump at low speed (gal/min)

= 30.6

EF_{vsL} = Energy Factor of variable speed pump at high speed (gal/Wh)

= 7.3

Days = Number of days per year that the swimming pool is operational

= 125[1000]

ΔkWh two speed = (((11.4 * 64.4 * 60)/2.1) - (((2* 56 * 60)/2.4 + ((15.7 * 31 * 60)/5.4))))/1000 * 125

= 1,596.0 kWh

ΔkWh variable speed = (((11.4 * 64.4 * 60)/2.1) - (((2* 50 * 60)/3.8 + ((16 * 30.6 * 60)/7.3))))/1000 * 125

= 1,921.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS [1001]

ΔkW two speed = $((kWh/day_{base})/(Hrs/day_{base}) – (kWh/day_{2sp})/(Hr/day_{2sp})) * CF$

ΔkW variable speed = $((kWh/day_{base})/(Hrs/day_{base}) – (kWh/day_{var})/(Hr/day_{var})) * CF$

Where:

kWh/day_{base} = daily energy consumption of baseline pump, as defined above

= 20.98

Hrs/day_{base} = daily run hours of single speed pump

= 11.4

kWh/day_{2sp} = daily energy consumption of two speed pump, as defined above

= 8.21

Hr/day_{2sp} = run hours of two speed pump

= 17.7

kWh/day_{var} = daily energy consumption of variable speed pump, as defined above

= 5.6

Hr/day_{var} = run hours of variable speed pump

= 18

[1000] Assumes 50% of pools operated from Memorial Day through Labor Day (100 days) and 50% of pools operate for a longer span, typically the 5 month period between May and September (150 days), due to their ability to heat the pool.

[1001] The methodology and all assumptions are sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.5 turnovers per day in the efficient case.

CF = Summer Peak Coincidence Factor for measure

= 0.831[1002]

ΔkW two speed = ((20.98 / 11.4) – (8.21 / 17.7)) * 0.831

= 1.144 kW

ΔkW variable speed = ((20.98 / 11.4) – (5.60 / 18)) * 0.831

= 1.271 kW

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-MSC-RPLP-V01-180101

REVIEW DEADLINE: 1/1/2022

[1002] Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.