Iowa Energy Efficiency Statewide Technical Reference Manual Version 4.0

Volume 2: Residential Measures

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Volume 2: Residential Measures

2.1 Appliances

2.1.1 Clothes Washer

Description

This measure relates to the installation of a clothes washer meeting the ENERGY STAR or CEE Tier 2 minimum qualifications. Note if the domestic hot water (DHW) and dryer fuels of the installations are unknown (for example through a retail program) savings are based on a weighted blend using RECS data (the resultant values (kWh, therms and gallons of water) are provided). The algorithms can also be used to calculate site specific savings where DHW and dryer fuels are known.

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

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

Definition of Efficient Equipment

Clothes washer must meet the ENERGY STAR or CEE Tier 2 minimum qualifications (provided in the table below), as required by the program.

Definition of Baseline Equipment

The baseline condition is a standard-sized clothes washer meeting the minimum federal baseline as of January 2018[1].

Efficiency Level		Top Loading >2.5 Cu ft	Front Loading >2.5 Cu ft
Baseline	Federal Standard	≥1.57 IMEF, ≤6.5 IWF	≥1.84 IMEF, ≤4.7 IWF
Efficient	ENERGY STAR	≥2.06 IMEF, ≤4.3 IWF	≥2.76 IMEF, ≤3.2 IWF
	CEE Tier 2		≥2.92 IMEF, ≤3.2 IWF

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

The Integrated Water Factor (IWF) indicates the total water consumption of the unit, with the lower the value the less water required; *"The quotient of the total weighted per-cycle water consumption for all 67 wash cycles in gallons divided by the cubic foot (or liter) capacity of the clothes washer."* [2].

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 14 years[3].

[1] See http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.
[2] Definitions provided in ENERGY STAR v8.0 specification on the ENERGY STAR website.
[3] Based on DOE Chapter 8 Life-Cycle Cost and Payback Period Analysis.

DEEMED MEASURE COST

The incremental cost assumptions are provided below[4]:

Efficiency Level	Incremental Cost	
	Top Loading	Front Loading
ENERGY STAR	$73	$121
CEE TIER 2	$193	$141

LOADSHAPE

Loadshape RE14 – Residential Clothes Washer

Loadshape G03 – Residential Dryer

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Capacity = Clothes Washer capacity (cubic feet)

= Actual – If capacity is unknown, assume 3.93 cubic feet[5]

IMEFbase = Integrated Modified Energy Factor of baseline unit

Efficiency Level	IMEFbase		
	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft	Weighted Average[6]
Federal Standard	1.57	1.84	1.84

IMEFeff = Integrated Modified Energy Factor of efficient unit

[4] Based on cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool. See '2017 Clothes Washer Analysis.xls' for details.

[5] Based on the average clothes washer volume of all units that pass the new Federal Standard and have an IMEF value on the CEC database of Clothes Washer products (accessed on 04/16/2017). If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

[6] Weighted average IMEF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR product in the CEC database (accessed 04/16/2017). The relative weightings are as follows, see more information in "2017 Clothes Washer Analysis.xlsx":

Efficiency Level	Front	Top
Baseline	98%	2%
ENERGY STAR	27%	73%
CEE Tier 2	100%	0%

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

Efficiency Level	IMEFeff		
	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft	Weighted Average[7]
ENERGY STAR	2.06	2.76	2.25
CEE Tier 2	2.92		2.92

Ncycles = Number of Cycles per year

= 250[8]

%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[9]		
	%CW	%DHW	%Dryer
Federal Standard	10%	22%	69%
ENERGY STAR	7%	24%	69%
CEE Tier 2	14%	10%	77%

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

DHW fuel	$\%Electric_{DHW}$
Electric	100%
Natural Gas	0%
Unknown	30.0%[10]

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

Dryer fuel	$\%Electric_{Dryer}$
Electric	100%
Natural Gas	0%

[7] Weighting is based upon the relative top v front loading percentage of available product in the CEC database (accessed 04/16/2017).

[8] Weighted average of 250 clothes washer cycles per year (based on 2015 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, West North Central Census Division: https://www.eia.gov/consumption/residential/data/2015/.See '2017 Clothes Washer Analysis.xls' for details.
If utilities have specific evaluation results providing a more appropriate assumption for single-family or multi-family homes, in a particular market, or geographical area then that should be used.

[9] The percentage of total energy consumption that is used for the machine, heating the hot water, or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units based on data from DOE Life-Cycle Cost and Payback Analysis. See '2017 Clothes Washer Analysis.xls' for details.

[10] Default assumption for unknown fuel is based on Dunsky and Opinion Dynamics Baseline Study. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used

Dryer fuel	$\%Electric_{Dryer}$
Unknown	87.1%[11]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below[12]:

Front Loaders:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	179.3	97.6	84.8	3.1
CEE Tier 2	198.8	115.3	89.4	5.8

Top Loaders:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	58.4	81.0	9.6	32.2
CEE Tier 2	198.8	180.6	56.4	38.2

Weighted Average:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	98.0	86.4	34.3	22.7
CEE Tier 2	198.8	115.3	89.4	5.8

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

	ΔkWH		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR	110.0	67.9	81.7
CEE Tier 2	126.3	167.8	126.3

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

[11] Default assumption for unknown is based on percentage of homes with clothes washers that use an electric dryer from EIA Residential Energy Consumption Survey (RECS) 2015 for Midwest Region, West North Central Census Division If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

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

ΔkWh = Energy Savings as calculated above

Hours = Assumed Run hours of Clothes Washer

= 250 hours[13]

CF = Summer Peak Coincidence Factor for measure

= 0.036[14]

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

Front Loaders:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0258	0.0141	0.0122	0.0005
CEE Tier 2	0.0286	0.0166	0.0129	0.0008

Top Loaders:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0084	0.0117	0.0014	0.0046
CEE Tier 2	0.0286	0.0260	0.0081	0.0055

Weighted Average:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0141	0.0124	0.0049	0.0033
CEE Tier 2	0.0286	0.0166	0.0129	0.0008

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

	ΔkW		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR	0.0158	0.0098	0.0118
CEE Tier 2	0.0182	0.0241	0.0182

13 Based on a weighted average of 250 clothes washer cycles per year assuming an average load runs for one hour.

14 Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, using IA definition of summer peak period.

Natural Gas Savings

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

Where:

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

DHW fuel	$\%Gas_{DHW}$
Electric	0%
Natural Gas	100%
Unknown	70.0%[15]

R_eff = Recovery efficiency factor

= 1.26[16]

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

Dryer fuel	$\%Gas_{Dryer}$
Electric	0%
Natural Gas	100%
Unknown	12.9%[17]

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

Other factors as defined above.

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

Front Loaders:

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0	3.5	3.2	6.7
CEE Tier 2	0.0	3.6	3.7	7.3

[15] Default assumption for unknown fuel is based on Dunsky and Opinion Dynamics Baseline Study results. 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.

[16] 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.

[17] Default assumption for unknown fuel is based EIA Residential Energy Consumption Survey (RECS) 2015 for Midwest Region, West North Central Census Division. 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. Note that the electric dryer percentage (76%) plus the gas dryer percentage (21.2%) equals 97.2%. The remaining 2.8% accounts for those homes without dryers.

Top Loaders:

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0	-1.0	1.7	0.7
CEE Tier 2	0.0	0.8	4.9	5.6

Weighted Average:

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0	0.5	2.2	2.7
CEE Tier 2	0.0	3.6	3.7	7.3

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

	ΔTherms		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR	2.9	-0.5	0.6
CEE Tier 2	3.0	1.2	3.0

PEAK GAS SAVINGS

Savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{365.25}$$

Where:

ΔTherms = Therm impact calculated above

365.25 = Days per year

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

Front Loaders:

	ΔPeakTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0000	0.0096	0.0088	0.0185
CEE Tier 2	0.0000	0.0098	0.0102	0.0201

Top Loaders:

	ΔPeakTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0000	-0.0027	0.0046	0.0019
CEE Tier 2	0.0000	0.0021	0.0133	0.0155

Weighted Average:

	ΔPeakTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0000	0.0014	0.0060	0.0073
CEE Tier 2	0.0000	0.0098	0.0102	0.0201

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

	ΔPeakTherms		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR	0.0079	-0.0013	0.0017
CEE Tier 2	0.0082	0.0032	0.0082

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Where:

IWFbase = Integrated Water Factor of baseline clothes washer

= 4.78[18]

IWFeff = Water Factor of efficient clothes washer

= Actual – If unknown assume average values provided below

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

	IWF[19]			ΔWater (gallons per year)		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average	Front Loaders	Top Loaders	Weighted Average
Federal Standard	4.7	6.5	4.73	N/A		
ENERGY STAR	3.2	4.3	4.01	1,504.2	423.7	711.8
CEE Tier 2	3.2		3.20	1,504.2	1504.2	1,550.3

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-CLWA-V04-200101

SUNSET DATE: 1/1/2023

18 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.

19 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 “2017 Clothes Washer Analysis.xls” for the calculation.

2.1.2 Clothes Dryer

Description

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR, ENERGY STAR Most Efficient criteria or a full heat pump clothes dryer. 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[20]. 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 16 years[21].

Deemed Measure Cost

The incremental cost for an ENERGY STAR clothes dryer is assumed to be as follows[22]

Product Class	Incremental Cost
Vented Electric, Standard (≥ 4.4 ft^3)	\$61
Ventless Electric, Standard (≥ 4.4 ft^3)	\$61
Most Efficient Vented Hybrid, Standard	\$127
Most Efficient Ventless Hybrid, Standard	\$127
Full Heat Pump, Standard	\$412
Vented Electric, Compact (120V) (< 4.4 ft^3)	\$31
Ventless Electric, Compact (120V) (< 4.4 ft^3)	\$31
Vented Electric, Compact (240V) (< 4.4 ft^3)	\$90
Ventless Electric, Compact (240V) (< 4.4 ft^3)	\$90
Vented Gas	\$104
Most Efficient Vented Gas	\$158

Loadshape

Loadshape RE14 – Residential Clothes Washer

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[20] 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

[21] Based on DOE Rulemaking Technical Support Document, LCC Chapter, 2011, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018

[22] Based upon data from DOE Life-Cycle Cost and Payback analysis, Table 8.3.1.

Loadshape G03 – Residential Dryer

Coincidence Factor

The coincidence factor for this measure is 4.31%[23]

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

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

Dryer Size	Load (lbs)[24]
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[25]. If product class unknown, assume electric, standard.

Product Class	CEFbase (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[26]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.[27] If product class unknown, assume electric, standard.

Product Class	CEFeff (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft^3)	3.93
Ventless Electric, Standard (≥ 4.4 ft^3)	3.93
Most Efficient Vented Hybrid, Standard	4.30
Most Efficient Ventless Hybrid, Standard	4.30

[23] Developed using coincident peak information from March 2015 NEEP, "Residential Electric Clothes Dryer Baseline Study" conducted by Energy Resource Solutions.https://neep.org/sites/default/files/resources/NEEP_EMV_Summary%20Report_Dryer%20Baseline%20Finale%204-01-15.pdf
[24] Based on ENERGY STAR test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[25] ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis
[26] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[27] ENERGY STAR Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

Product Class	CEFeff (lbs/kWh)
Full Heat Pump, Standard	10.40[28]
Vented Electric, Compact (120V) (< 4.4 ft^3)	3.80
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[29]
Most Efficient Vented Gas	3.80

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 250 cycles per year.[30]

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 16% for gas dryers[31]

PairedWasherkWhAdj = Adjustment to account for new clothes dryers often being purchased paired with an ENERGY STAR clothes washer (from which dryer savings are being claimed)[32]

Product Class	PairedWasherAdj (kWh)
Vented Electric, Standard (≥ 4.4 ft^3)	44.6
Ventless Electric, Standard (≥ 4.4 ft^3)	44.6
Most Efficient Vented Hybrid, Standard	44.6
Most Efficient Ventless Hybrid, Standard	44.6
Full Heat Pump, Standard	44.6
Vented Electric, Compact (120V) (< 4.4 ft^3)	0
Ventless Electric, Compact (120V) (< 4.4 ft^3)	0
Vented Electric, Compact (240V) (< 4.4 ft^3)	0
Ventless Electric, Compact (240V) (< 4.4 ft^3)	0
Vented Gas	0
Most Efficient Vented Gas	0

ΔkWhHEAT = Electric space heating impact due to waste heat either being predominately vented to

[28] This represents the test results performed with 8.45 lb load (the standard test load size used by manufacturers for reporting performance), See 'Blomberg "Energy Star Partner Meeting – SEDI Session October 14, 2015." This is based upon single full heat pump models (Blomberg/Beko) available now in the US. This will be updated when additional equipment enters the market and/or when separate CEE/ESTAR specifications are released for Heat Pump Dryers.

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

[30] Weighted average of 250 clothes washer cycles per year, consistent with Clothes Washer measure and based on 2015 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, West North Central Census Division: https://www.eia.gov/consumption/residential/data/2015/. See RECS-Appliances tab in 'Clothes Dryer_Analysis_05082019.xlsx' for calculation.
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.
http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Dryer%20Specification%20NEEA%20Amended%20comments%20Mar%2026%202013.pdf. Page 7.

[31] %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. See ENERGY STAR Analysis tab in 'Clothes Dryer_Analysis_05082019.xlsx' for calculation.

[32] Dryer savings are calculated within the Clothes Washer measure. See "Clothes Dryer Calcs_04262017.xls" for more detail.

outside or remaining in the home (ventless hybrid or heat pump)

= kWhHEATEff - kWhHEATBase

kWhHEAT = (%HeatSpace * HF * %ElecHeat * %Conditioned * Dryer Consumption) / $\eta Heat_{Electric}$

Where:

%HeatSpace = Proportion of dryer heat energy remaining in space

Vented = 5%[33]

Ventless = 100%

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

= 59% for unit in heated space or unknown [34]

= 0% for unit in unheated space

%ElecHeat = Percentage of home with electric heat

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

%Conditioned = Portion of homes with dryer in conditioned space

= 73%[36]

Dryer Consumption = Load/CEF * Ncycles

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

= Actual system efficiency including duct loss – If not available, use[37]:

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

[33] Professional judgement estimate.
[34] Based on 217 days where HDD 60>0, divided by 365.25.
[35] Based on Dunsky and Opinion Dynamics Baseline Study results.
[36] NEEP Study found 16 of 22 sites had the dryer in a heated space; NEEP, Energy & Resource Solutions "Electric Dryer Baseline Research", p8. http://www.neep.org/sites/default/files/Microsoft%20PowerPoint%20-%20NEEP%20Dryer%20Presentation%20Final%2003-30-15.pdf
[37] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Unknown	N/A	N/A	1.27[38]

ΔkWhCOOL = Cooling impact due to waste heat either being predominately vented to outside or remaining in the home (ventless hybrid or heat pump)

= $kWhCOOL_{Base}$ - $kWhCOOL_{Eff}$

kWhCOOL = (%HeatSpace * CoolF * %Cool * %Conditioned * Dryer Consumption) / ηCool

Where:

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

= 34% for unit in cooled space or unknown [39]

= 0% for unit in uncooled space

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	88%[40]

ηCool = Efficiency in COP of Cooling equipment

= Actual – If not available, assume 2.8 COP[41]

Using defaults provided above:

Product Class	CEF base	CEF eff	Base Dryer Consumption (kWh)	Eff Dryer Consumption (kWH)	Paired Washer kWhAdj	kWh HEAT Base (kWh)	kWh HEAT Eff (kWh)	kWh COOL Base (kWh)	kWh COOL Eff (kWh)	Total Waste Heat Impact	ΔkWh
Vented Electric, Standard (≥ 4.4 ft³)	3.11	3.93	679.5	537.7	44.6	2.0	1.6	2.7	2.1	0.1	97.3
Ventless Electric, Standard (≥ 4.4 ft³)	3.11	3.93	679.5	537.7	44.6	2.0	31.0	2.7	41.9	-10.3	86.9
Most Efficient Vented Hybrid, Standard	3.11	4.3	679.5	491.4	44.6	2.0	1.4	2.7	1.9	0.2	143.6
Most Efficient Ventless Hybrid, Standard	3.11	4.3	679.5	491.4	44.6	2.0	28.3	2.7	38.3	-9.3	134.1
Full Heat Pump, Standard	3.11	10.4	679.5	203.2	44.6	2.0	11.7	2.7	15.9	-3.4	428.2

[38] Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.
[39] Based on 123 days where CDD 65>0, divided by 365.25.
[40] Based on Dunsky and Opinion Dynamics Baseline Study results.
[41] Starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * $SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

Product Class	CEF base	CEF eff	Base Dryer Consumption (kWh)	Eff Dryer Consumption (kWH)	Paired Washer kWhAdj	kWh HEAT Base (kWh)	kWh HEAT Eff (kWh)	kWh COOL Base (kWh)	kWh COOL Eff (kWh)	Total Waste Heat Impact	ΔkWh
Vented Electric, Standard (≥ 4.4 ft³)	3.11	3.93	679.5	537.7	44.6	2.0	1.6	2.7	2.1	0.1	97.3
Vented Electric, Compact (120V) (< 4.4 ft³)	3.01	3.8	249.3	197.4	0.0	0.7	0.6	1.0	0.8	0.1	51.9
Ventless Electric, Compact (120V) (< 4.4 ft³)	3.01	3.8	249.3	197.4	0.0	14.4	11.4	19.4	15.4	1.1	52.9
Vented Electric, Compact (240V) (< 4.4 ft³)	2.73	3.45	274.8	217.5	0.0	0.8	0.6	1.1	0.8	0.1	57.4
Ventless Electric, Compact (240V) (< 4.4 ft³)	2.13	2.68	352.2	279.9	0.0	20.3	16.1	27.5	21.8	1.5	73.8
Vented Gas	2.84	3.48	118.2	96.4	0.0	2.1	1.8	2.9	2.4	0.1	21.9
Most Efficient Vented Gas	2.84	3.8	118.2	88.3	0.0	2.1	1.6	2.9	2.2	0.2	30.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer. Use actual data if available. If unknown, use 200 hours per year.[42]

CF = Summer Peak Coincidence Factor for measure

=4.31%[43]

Using defaults provided above:

Product Class	ΔkW
Vented Electric, Standard (≥ 4.4 ft³)	0.0210
Ventless Electric, Standard (≥ 4.4 ft³)	0.0187
Most Efficient Vented Hybrid, Standard	0.0309
Most Efficient Ventless Hybrid, Standard	0.0289
Full Heat Pump, Standard	0.0923
Vented Electric, Compact (120V) (< 4.4 ft³)	0.0112
Ventless Electric, Compact (120V) (< 4.4 ft³)	0.0114
Vented Electric, Compact (240V) (< 4.4 ft³)	0.0124
Ventless Electric, Compact (240V) (< 4.4 ft³)	0.0159
Vented Gas	0.0047
Most Efficient Vented Gas	0.0065

[42] Assume 250 cycles and 48 minutes per dryer cycle according to March 2015 NEEP "Residential Electric Clothes Dryer Baseline Study" conducted by Energy Resource Solutions. https://neep.org/sites/default/files/resources/NEEP_EMV_Summary%20Report_Dryer%20Baseline%20Finale%204-01-15.pdf

[43] Developed using coincident peak information from March 2015 NEEP, "Residential Electric Clothes Dryer Baseline Study" conducted by Energy Resource Solutions. https://neep.org/sites/default/files/resources/NEEP_EMV_Summary%20Report_Dryer%20Baseline%20Finale%204-01-15.pdf

Natural Gas Energy Savings

Natural Gas Savings

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

$$\Delta Therm = \left(\left(\frac{Load}{CEFbase} - \frac{Load}{CEFeff}\right) * Ncycles * Therm_{convert} * \%Gas\right) - PairedWasherThermAdj + \Delta ThermHEAT$$

Where:

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

%Gas = Percent of overall savings coming from gas

= 0% for electric units and 84% for gas units[44]

PairedWasherThermAdj = Adjustment to account for new clothes dryers being purchased paired with an ENERGY STAR clothes washer (from which some dryer savings are already being claimed)

Product Class	PairedWasherAdj (Therm)
Vented Electric, Standard (≥ 4.4 ft^3)	0
Ventless Electric, Standard (≥ 4.4 ft^3)	0
Most Efficient Vented Hybrid, Standard	0
Most Efficient Ventless Hybrid, Standard	0
Full Heat Pump, Standard	0
Vented Electric, Compact (120V) (< 4.4 ft^3)	0
Ventless Electric, Compact (120V) (< 4.4 ft^3)	0
Vented Electric, Compact (240V) (< 4.4 ft^3)	0
Ventless Electric, Compact (240V) (< 4.4 ft^3)	0
Vented Gas	1.5
Most Efficient Vented Gas	1.5

ΔThermHEAT = Gas spaced heating impact due to waste heat either being predominately vented to outside or remaining in the home (ventless hybrid or heat pump)

= ThermHEATEff - ThermHEATBase

ThermHEAT = (%HeatSpace * HF * %GasHeat * %Conditioned * Dryer Consumption) / $\eta Heat_{Gas}$

Where:

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83%[45]

[44] %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. See ENERGY STAR Analysis tab in 'Clothes Dryer_Analysis_05082019.xlsx' for calculation.
[45] Based on Dunsky and Opinion Dynamics Baseline Study results.

Dryer Consumption = Load/CEF * Ncycles

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

=74%[46]

<table>
<tr><th>Product Class</th><th>CEF base</th><th>CEFeff</th><th>Base Dryer Consumption (Therms)</th><th>Eff Dryer Consumption (Therms)</th><th>Paired Washer Therm Adj</th><th>Therm HEAT Base</th><th>Therm HEAT Eff</th><th>Total Waste Heat Impact</th><th>ΔTherm</th></tr>
<tr><td>Vented Electric, Standard (≥ 4.4 ft³)</td><td colspan="5" rowspan="9">n/a</td><td>0.56</td><td>0.44</td><td>-0.12</td><td>-0.12</td></tr>
<tr><td>Ventless Electric, Standard (≥ 4.4 ft³)</td><td>0.56</td><td>8.86</td><td>8.30</td><td>8.30</td></tr>
<tr><td>Most Efficient Vented Hybrid, Standard</td><td>0.56</td><td>0.41</td><td>-0.15</td><td>-0.15</td></tr>
<tr><td>Most Efficient Ventless Hybrid, Standard</td><td>0.56</td><td>8.10</td><td>7.54</td><td>7.54</td></tr>
<tr><td>Full Heat Pump, Standard</td><td>0.56</td><td>3.35</td><td>2.79</td><td>2.79</td></tr>
<tr><td>Vented Electric, Compact (120V) (< 4.4 ft³)</td><td>0.21</td><td>0.16</td><td>-0.04</td><td>-0.04</td></tr>
<tr><td>Ventless Electric, Compact (120V) (< 4.4 ft³)</td><td>4.11</td><td>3.25</td><td>-0.85</td><td>-0.85</td></tr>
<tr><td>Vented Electric, Compact (240V) (< 4.4 ft³)</td><td>0.23</td><td>0.18</td><td>-0.05</td><td>-0.05</td></tr>
<tr><td>Ventless Electric, Compact (240V) (< 4.4 ft³)</td><td>5.81</td><td>4.61</td><td>-1.19</td><td>-1.19</td></tr>
<tr><td>Vented Gas</td><td>2.84</td><td>0.61</td><td>0.50</td><td>-0.11</td><td>2.29</td><td>0.64</td><td>0.52</td><td>-0.12</td><td>3.01</td></tr>
<tr><td>Most Efficient Vented Gas</td><td>2.84</td><td>0.61</td><td>0.46</td><td>-0.15</td><td>3.72</td><td>0.64</td><td>0.48</td><td>-0.16</td><td>4.70</td></tr>
</table>

PEAK GAS SAVINGS

Savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{365.25}$$

Where:

[46] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes - based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

ΔTherms = Therm impact calculated above

365.25 = Days per year

Product Class	ΔPeak Therms
Vented Electric, Standard (≥ 4.4 ft^3)	-0.0003
Ventless Electric, Standard (≥ 4.4 ft^3)	0.0227
Most Efficient Vented Hybrid, Standard	-0.0004
Most Efficient Ventless Hybrid, Standard	0.0206
Full Heat Pump, Standard	0.0076
Vented Electric, Compact (120V) (< 4.4 ft^3)	-0.0001
Ventless Electric, Compact (120V) (< 4.4 ft^3)	-0.0023
Vented Electric, Compact (240V) (< 4.4 ft^3)	-0.0001
Ventless Electric, Compact (240V) (< 4.4 ft^3)	-0.0033
Vented Gas	0.0063
Most Efficient Vented Gas	0.0102

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESDR-V04-200101

SUNSET DATE: 1/1/2023

2.1.3 Refrigerator

Description

A refrigerator meeting either Energy Star/CEE Tier 1 specifications or the higher efficiency specifications of CEE Tier 2, or CEE Tier 3 is installed instead of a new unit of baseline efficiency. The measure applies to time of sale and early replacement programs.

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

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

Definition of Efficient Equipment

The high efficiency level is a refrigerator meeting Energy Star specifications effective September 15th, 2014 (10% above federal standard), a refrigerator meeting CEE Tier 2 specifications (15% above federal standard), or meeting CEE Tier 3 specifications (20% above federal standards).

Definition of Baseline Equipment

Baseline efficiency is a new refrigerator meeting the minimum federal efficiency standard for refrigerators effective September 15th, 2014.

Deemed Lifetime of Efficient Equipment

17 years[47]

Deemed Measure Cost

The full cost of a baseline unit is $803.[48]

The incremental cost to the Energy Star level is $12, to CEE Tier 2 level is $21 and to CEE Tier 3 is $59.[49]

Loadshape

Loadshape RE16 – Residential Refrigeration

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

[47] Mean from Figure 8.2.3, DOE, 2011-08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers.

[48] Configurations weighted according to table under Energy Savings. Values inflated 13.2% (cumulative rate of inflation using government CPI data) from 2009 dollars to 2017. Table 8.1.1, DOE, 2011-08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers. See 'Refrig Incremental Cost Calc. xls' for details.

[49] Configurations weighted according to table under Energy Savings. Values inflated 8.9% from 2009 dollars to 2015. Table 8.2.2, DOE, 2011-08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers. See 'Refrig Incremental Cost Calc. xls' for details.

kWh_{base} = Baseline consumption

= Based on average consumption of non-ENERGY STAR units available in 4 main product classes. See tables below[50].

%Savings = Specification of energy consumption below Federal Standard:

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

Additional Waste Heat Impacts

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

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

Where:

ΔkWh = kWh savings calculated from either method above

WHFeHeatElectric= Waste Heat Factor for Energy to account for electric heating increase from removing waste heat from refrigerator/freezer (if fossil fuel heating – see calculation of heating penalty in that section).

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

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

= 59% for unit in heated space or unknown [51]

= 0% for unit in unheated space

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

= Actual system efficiency including duct loss – If not available, use[52]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 – 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.27[53]

[50] See 'Refrig_CAC database_04262017.XLS' for more information.
[51] Based on 217 days where HDD 60>0, divided by 365.25.
[52] 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.
[53] Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.

%ElecHeat = Percentage of home with electric heat

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	17%[54]

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

= (CoolF / ηCool) * %Cool

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

= 34% for unit in cooled space or unknown [55]

= 0% for unit in uncooled space

ηCool = Efficiency in COP of Cooling equipment

= Actual – If not available, assume 2.8 COP[56]

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	88%[57]

Default assumptions are provided below:

Product Class	Baseline Usage kWh_{base}	Unit ΔkWh			$\Delta kWh_{WasteHeat}$			Total ΔkWh		
		ENERGY STAR / CEE Tier 1	CEE Tier 2	CEE Tier 3	ENERGY STAR / CEE Tier 1	CEE Tier 2	CEE Tier 3	ENERGY STAR / CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	472.1	15.9	55.2	93.4	0.4	1.5	2.6	16.3	56.7	96.0
Side-by-Side w/ TTD (PC 7)	707.8	64.8	103.8	149.3	1.8	2.9	4.2	66.6	106.7	153.4
Bottom Freezer (PC 5)	551.8	35.7	67.4	104.5	1.0	1.9	2.9	36.7	69.3	107.4
Bottom Freezer w/ TTD (PC 5A)	656.9	39.1	81.6	118.8	1.1	2.3	3.3	40.2	83.9	122.1

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

---

[54] Based on Dunsky and Opinion Dynamics Baseline Study results.
[55] Based on 123 days where CDD 65>0, divided by 365.25.
[56] Starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * $SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).
[57] Based on Dunsky and Opinion Dynamics Baseline Study results.

Product Class	Market Weight[58]	Total ΔkWh			$\Delta kWh_{WasteHeat}$			Total ΔkWh		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3	Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3	Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	52%	32.2	70.9	110.4	0.9	2.0	3.1	33.1	72.9	113.5
Side-by-Side w/ TTD (PC 7)	22%									
Bottom Freezer (PC 5)	13%									
Bottom Freezer w/ TTD (PC 5A)	13%									

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\frac{\Delta kWh_{Unit}}{HOURS}\right) * WHFdCool * CF$$

Where:

ΔkWh_{Unit} = gross customer connected load kWh savings for the measure (not including $\Delta kWh_{wasteheat}$)

HOURS = Equivalent Full Load Hours

= 5280[59]

WHFdCool = Waste heat factor for demand to account for cooling savings from removing waste heat.

Refrigerator Location	WHFdCool
Cooled space	1.22[60]
Uncooled	1.0
Unknown	1.19[61]

CF = Summer Peak Coincident Factor

= 0.709 [62]

Default assumptions are provided below:

Product Class	ΔkW		
	Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	0.0025	0.0088	0.0149
Side-by-Side w/ TTD (PC 7)	0.0104	0.0166	0.0239
Bottom Freezer (PC 5)	0.0057	0.0108	0.0167
Bottom Freezer w/ TTD (PC 5A)	0.0062	0.0130	0.0190

[58] Personal Communication from Melisa Fiffer, ENERGY STAR Appliance Program Manager, EPA 10/26/14
[59] Based on analysis of loadshape data provided by Cadmus.
[60] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour), consistent with the lighting peak hours.
[61] The value is estimated at 1.19 (calculated as 1 + (0.88 * 0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour), consistent with the lighting peak hours. The 88% is the percentage of homes have central cooling (based on Dunsky and Opinion Dynamics Baseline Study results).
[62] Based on analysis of loadshape data provided by Cadmus.

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

Product Class	Market Weight[63]	ΔkW		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	52%	0.0052	0.0113	0.0176
Side-by-Side w/ TTD (PC 7)	22%			
Bottom Freezer (PC 5)	13%			
Bottom Freezer w/ TTD (PC 5A)	13%			

Natural Gas Savings

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

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

Where:

ΔkWh_{Unit} = kWh savings calculated from either method above, not including the $\Delta kWh_{WasteHeat}$

WHFeHeatGas = Waste Heat Factor for Energy to account for gas heating increase from removing waste heat from refrigerator/freezer

= - (HF / $\eta Heat_{Gas}$) * %GasHeat

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

= 59% for unit in heated space or unknown [64]

= 0% for unit in unheated space

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

=74%[65]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83%[66]

0.03412 = Converts kWh to Therms

Default assumptions are provided below:

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

[64] Based on 217 days where HDD 60>0, divided by 365.25.

[65] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes - based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

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

Product Class	ΔTherms		
	Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	-0.36	-1.25	-2.11
Side-by-Side w/ TTD (PC 7)	-1.46	-2.34	-3.37
Bottom Freezer (PC 5)	-0.81	-1.52	-2.36
Bottom Freezer w/ TTD (PC 5A)	-0.88	-1.84	-2.68

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

Product Class	Market Weight[67]	ΔTherms		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	52%	-0.73	-1.60	-2.49
Side-by-Side w/ TTD (PC 7)	22%			
Bottom Freezer (PC 5)	13%			
Bottom Freezer w/ TTD (PC 5A)	13%			

PEAK GAS SAVINGS

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

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{(\ \Delta Therms)}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[68]

Default assumptions are provided below:

Product Class	ΔPeakTherms		
	Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	-0.0017	-0.0057	-0.0097
Side-by-Side w/ TTD (PC 7)	-0.0067	-0.0108	-0.0155
Bottom Freezer (PC 5)	-0.0037	-0.0070	-0.0109
Bottom Freezer w/ TTD (PC 5A)	-0.0041	-0.0085	-0.0124

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

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

[68] Number of days where HDD 60 >0.

Product Class	Market Weight[69]	∆PeakTherms		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Top Freezer (PC 3)	52%	-0.0034	-0.0074	-0.0115
Side-by-Side w/ TTD (PC 7)	22%			
Bottom Freezer (PC 5)	13%			
Bottom Freezer w/ TTD (PC 5A)	13%			

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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

SUNSET DATE: 1/1/2021

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

2.1.4 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)	Federal Baseline Maximum Energy Usage in kWh/year[70]	ENERGY STAR Maximum Energy Usage in kWh/year[71]
Upright Freezers with Manual Defrost	7.75 or greater	5.57*AV + 193.7	5.01*AV + 174.3
Upright Freezers with Automatic Defrost without an automatic icemaker	7.75 or greater	8.62*AV + 228.3	7.76*AV + 205.5
Upright Freezers with Automatic Defrost with an automatic icemaker	7.75 or greater	8.62*AV+312.3	7.76*AV+289.5
Built-In Upright freezeres with automatic defrost without an automatic icemaker	7.75 or greater	9.86*AV+260.9	8.87*AV+234.8
Built-In Upright freezeres with automatic defrost with an automatic icemaker	7.75 or greater	9.86*AV+344.9	8.87*AV+318.8
Chest Freezers and all other Freezers except Compact Freezers	7.75 or greater	7.29*AV + 107.8	6.56*AV + 97.0
Chest Freezers with automatic defrost	7.75 or greater	10.24*AV+148.1	9.22*AV+133.3
Compact Upright Freezers with Manual Defrost	< 7.75 and 36 inches or less in height	8.65*AV + 225.7	7.79*AV + 203.1
Compact Upright Freezers with Automatic Defrost	< 7.75 and 36 inches or less in height	10.17*AV + 351.9	9.15*AV + 316.7
Compact Chest Freezers	<7.75 and 36 inches or less in height	9.25*AV + 136.8	8.33*AV + 123.1

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

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

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, defined as using at least 10% less measured energy than the minimum federal efficiency standards.

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.

[70] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
[71] http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 12 years[72].

Deemed Measure Cost

The incremental cost for this measure is $0[73].

Loadshape

Loadshape RE15 – Residential Freezer

Algorithm

Calculation of Savings

Electric Energy Savings:

$$\Delta kWh_{Unit} = kWh_{BASE} - kWh_{ESTAR}$$

Where:

kWh_{BASE} = Baseline kWh consumption per year.

= Based on average consumption of non-ENERGY STAR units available in 4 main product classes. See tables below.

kWh_{ESTAR} = ENERGY STAR kWh consumption per year

Additional Waste Heat Impacts

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

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

Where:

ΔkWh = kWh savings calculated from either method above

WHFeHeatElectric= Waste Heat Factor for Energy to account for electric heating increase from removing waste heat from refrigerator/freezer (if fossil fuel heating – see calculation of heating penalty in that section).

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

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

= 59% for unit in heated space or unknown [74]

= 0% for unit in unheated space

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

= Actual system efficiency including duct loss – If not available, use[75]:

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72 2012 EPA research on available models, as cited in the 2015 Energy Star Freezer Calculator; http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

73 2014 EPA research on available models, as cited in the 2015 Energy Star Freezer Calculator; http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

74 Based on 217 days where HDD 60>0, divided by 365.25.

75 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

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 – 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.27[76]

%ElecHeat = Percentage of home with electric heat

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	19%[77]

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

= (CoolF / ηCool) * %Cool

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

= 34% for unit in cooled space or unknown [78]

= 0% for unit in uncooled space

ηCool = Efficiency in COP of Cooling equipment

= Actual – If not available, assume 2.8 COP[79]

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	88%[80]

Default assumptions are provided below:

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.

[76] Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.

[77] Based on Dunsky and Opinion Dynamics Baseline Study results.

[78] Based on 123 days where CDD 65>0, divided by 365.25.

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

[80] Based on Dunsky and Opinion Dynamics Baseline Study results.

Product Category	kWh_{BASE}	kWh_{ESTAR}	Unit kWh Savings	$\Delta kWh_{WasteHeat}$	Total ΔkWh
Upright Freezers	494.1	423.0	71.1	2.0	73.1
Chest Freezers	248.3	195.2	53.1	1.5	54.6
Compact Upright Freezers	190.0	159.9	30.1	0.8	30.9
Compact Chest Freezers	248.3	195.2	53.1	1.5	54.6

If product class is also unknown, the following table provides a market weighting to be applied to give a single deemed savings:

Product Class	Market Weight[81]	Unit kWh Savings	$\Delta kWh_{WasteHeat}$	Total ΔkWh
Upright Freezer	55%	62.8	1.8	64.6
Chest Freezer	32%			
Compact Upright Freezer	4%			
Compact Chest Freezer	9%			

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh_{Unit}}{Hours} * WHFdCool * CF$$

Where:

ΔkWh_{Unit} = Gross customer annual kWh savings for the measure (not including $\Delta kWh_{wasteheat}$)

Hours = Full Load hours per year

= 5895[82]

WHFdCool = Waste heat factor for demand to account for cooling savings from removing waste heat.

Freezer Location	WHFdCool
Cooled space	1.22[83]
Uncooled	1.0
Unknown	1.19[84]

CF = Summer Peak Coincident Factor

= 0.953 [85]

Default assumptions are provided below:

[81] Weighted based on numbers of models available in the California Energy Commission Appliance Efficiency Program. https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx.

[82] Based on analysis of loadshape data provided by Cadmus.

[83] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour), consistent with the lighting peak hours.

[84] The value is estimated at 1.19 (calculated as 1 + (0.88 * 0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour), consistent with the lighting peak hours. The 88% is the percentage of homes have central cooling (based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region.xls").

[85] Based on analysis of loadshape data provided by Cadmus.

Product Category	kW Savings
Upright Freezers	0.0137
Chest Freezers	0.0102
Compact Upright Freezers	0.0193
Compact Chest Freezers	0.0058

If product class is unknown, the following table provides a market weighting to be applied to give a single deemed savings:

Product Class	Market Weight[86]	kW Savings
Upright Freezer	55%	0.0121
Chest Freezer	32%	
Compact Upright Freezer	4%	
Compact Chest Freezer	9%	

NATURAL GAS SAVINGS

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

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

Where:

ΔkWh_{Unit} = kWh savings calculated from either method above, not including the $\Delta kWh_{WasteHeat}$

WHFeHeatGas = Waste Heat Factor for Energy to account for gas heating increase from removing waste heat from refrigerator/freezer

= - (HF / $\eta Heat_{Gas}$) * %GasHeat

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

= 59% for unit in heated space or unknown [87]

= 0% for unit in unheated space

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

=74%[88]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%

[86] Weighted based on numbers of models available in the California Energy Commission Appliance Efficiency Program. https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx.

[87] Based on 217 days where HDD 60>0, divided by 365.25.

[88] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes - based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

Heating Fuel	%GasHeat
Gas	100%
Unknown	83%[89]

0.03412 = Converts kWh to Therms

Default assumptions are provided below:

Product Category	ΔTherms
Upright Freezers	-1.61
Chest Freezers	-1.20
Compact Upright Freezers	-2.27
Compact Chest Freezers	-0.68

If product class is unknown, the following table provides a market weighting to be applied to give a single deemed savings:

Product Class	Market Weight[90]	ΔTherms
Upright Freezer	55%	-1.42
Chest Freezer	32%	
Compact Upright Freezer	4%	
Compact Chest Freezer	9%	

PEAK GAS SAVINGS

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

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{(\Delta Therms)}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[91]

Default assumptions are provided below:

Product Category	ΔTherms
Upright Freezers	-0.0074
Chest Freezers	-0.0055
Compact Upright Freezers	-0.0104
Compact Chest Freezers	-0.0031

[89] Based on data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls".
[90] Weighted based on numbers of models available in the California Energy Commission Appliance Efficiency Program. https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx.
[91] Number of days where HDD 60 >0.

If product class is unknown, the following table provides a market weighting to be applied to give a single deemed savings:

Product Class	Market Weight[92]	ΔTherms
Upright Freezer	55%	-0.0065
Chest Freezer	32%	
Compact Upright Freezer	4%	
Compact Chest Freezer	9%	

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESFR-V02-180101

SUNSET DATE: 1/1/2021

[92] Weighted based on numbers of models available in the California Energy Commission Appliance Efficiency Program. https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx.

2.1.5 Refrigerator and Freezer Recycling

Description

This measure describes savings from the retirement and recycling of inefficient but operational refrigerators and freezers. Savings are provided in two ways. First, a regression equation is provided that requires the use of key inputs describing the retired unit (or population of units) and is based on a 2013 workpaper provided by Cadmus that used data from a 2012 ComEd metering study and metering data from a Michigan study. The second methodology is a deemed approach based on an evaluation of 2016 Ameren Illinois Company Appliance Recycling Program..

The savings are equivalent to the Unit Energy Consumption of the retired unit and should be claimed for the assumed remaining useful life of that unit. A part-use factor is applied to account for those secondary units that are not in use throughout the entire year. The user should note that the regression algorithm is designed to provide an accurate portrayal of savings for the population as a whole and includes those parameters that have a significant effect on the consumption. The precision of savings for individual units will vary. This measure also includes a section accounting for the interactive effect of reduced waste heat on the heating and cooling loads.

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

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

Definition of Efficient Equipment

The existing inefficient refrigerator is removed from service and not replaced.

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The estimated remaining useful life of the recycling units is 6.5 years [93].

Deemed Measure Cost

Measure cost includes the cost of pickup and recycling of the refrigerator and should be based on actual costs of running the program. If unknown, assume $120[94] per unit.

Loadshape

Loadshape RE16 – Residential Refrigerator

Loadshape RE15 – Residential Freezer

[93] DOE refrigerator and freezer survival curves are used to calculate RUL for each equipment age and develop a RUL schedule. The RUL of each unit in the ARCA database is calculated and the average RUL of the dataset serves as the final measure RUL. Refrigerator recycling data from ComEd, IL (PY7-PY9) and Ameren, IL (PY6-PY8) were used to determined EUL with the DOE survival curves from the 2009 TSD. A weighted average of the retailer ComEd data and the Ameren data results in an average of 6.5 years. See Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[94] Based on similar Efficiency Vermont program.

Algorithm

Calculation of Savings

Energy Savings

Regression analysis; Refrigerators

Energy savings for refrigerators are based upon a linear regression model using the following coefficients[95]:

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

$$\Delta kWh_{Unit} = [83.32 + (Age * 3.68) + (Pre-1990 * 485.04) + (Size * 27.15) + (Side-by-side * 406.78) + (Primary\ Usage * 161.86) + (CDD/365.25 * unconditioned * 15.37) + (HDD/365.25 * unconditioned * -11.07)] * Part\ Use\ Factor$$

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)

Single-Door = Single-door dummy (= 1 if Single-door, else 0)

Primary Usage = Primary Usage Type (in absence of the program) dummy (= 1 if Primary, else 0)

CDD = Cooling Degree Days

= Dependent on location[96]:

Climate Zone (City based upon)	CDD 65	CDD/365.25
5 (Burlington)	1209	3.31
6 (Mason City)	616	1.69
Average/unknown (Des Moines)	1,068	2.92

[95] Coefficients provided in July 30, 2014 memo from Cadmus: "Appliance Recycling Update no single door July 30 2014". 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.

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

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

Note unconditioned means a space that is not intentionally heated via furnace vents or boiler radiators. The presence of and/or leakage from a heating system in a space doesn't in itself imply the space is conditioned.

HDD = Heating Degree Days

= Dependent on location:[97]

Climate Zone (City based upon)	HDD 60	HDD/365.25
5 (Burlington)	4,496	12.31
6 (Mason City)	6,391	17.50
Average/unknown (Des Moines)	5,052	13.83

Part Use Factor = To account for those units that are not running throughout the entire year. If available, part-use factor participant survey results should be used. If not available, assume 0.91.[98]

Deemed approach; Refrigerators

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

Where:

UEC = Unit Energy Consumption

= 1032 kWh[99]

Part Use Factor = To account for those units that are not running throughout the entire year. If available, part-use factor participant survey results should be used. If not available, assume 0.91.[100]

ΔkWh_{Unit} = 1032 * 0.91

= 939.12 kWh

Regression analysis; Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients[101]:

97 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.

98 Estimated using PY6 Illinois survey responses. Page 12, Impact and Process Evaluation of 2016 (PY9) Ameren Illinois Company Appliance Recycling Program, Opinion Dynamics, October 13, 2017.

99 Table 11. PY9 Mean Explanatory Variables, Impact and Process Evaluation of 2016 (PY9) Ameren Illinois Company Appliance Recycling Program, Opinion Dynamics, October 13, 2017.

100 Estimated using PY6 Illinois survey responses. Page 12, Impact and Process Evaluation of 2016 (PY9) Ameren Illinois Company Appliance Recycling Program, Opinion Dynamics, October 13, 2017.

101 Coefficients provided in January 31, 2013 memo from Cadmus: "Appliance Recycling Update". 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.

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

$$\Delta kWh_{Unit} = [132.12 + (Age * 12.13) + (Pre-1990 * 156.18) + (Size * 31.84) + (Chest\ Freezer * -19.71) + (CDD/365.25 * unconditioned * 9.78) + (HDD/365.25 * unconditioned * -12.75)] * Part\ Use\ Factor$$

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)

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

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

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

Part Use Factor = To account for those units that are not running throughout the entire year. If available, part-use factor participant survey results should be used. If not available, assume 0.86.[102]

Deemed approach; Freezers

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

Where:

$UEC_{Retired}$ = Unit Energy Consumption of retired unit

= 944 kWh[103]

Part Use Factor = To account for those units that are not running throughout the entire year. If available, part-use factor participant survey results should be used. If not available, assume 0.86.[104]

ΔkWh_{Unit} = 944 * 0.86

= 811.8 kWh

[102] Estimated using PY6 Illinois survey responses. Page 12, Impact and Process Evaluation of 2016 (PY9) Ameren Illinois Company Appliance Recycling Program, Opinion Dynamics, October 13, 2017.
[103] Table 11. PY9 Mean Explanatory Variables, Impact and Process Evaluation of 2016 (PY9) Ameren Illinois Company Appliance Recycling Program, Opinion Dynamics, October 13, 2017.
[104] Estimated using PY6 Illinois survey responses. Page 12, Impact and Process Evaluation of 2016 (PY9) Ameren Illinois Company Appliance Recycling Program, Opinion Dynamics, October 13, 2017.

Additional Waste Heat Impacts

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

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

Where:

ΔkWh_{unit} = kWh savings calculated from either method above

WHFeHeatElectric = Waste Heat Factor for Energy to account for electric heating increase from removing waste heat from refrigerator/freezer (if fossil fuel heating – see calculation of heating penalty in that section).

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

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

= 59% for unit in heated space[105]

= 0% for unit in unheated space or unknown

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

= Actual system efficiency including duct loss – If not available, use[106]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 – 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.27[107]

%ElecHeat = Percentage of home with electric heat

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	17%[108]

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

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105 Based on 217 days where HDD 60>0, divided by 365.25.

106 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.

107 Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”. Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.

108 Based on Dunsky and Opinion Dynamics Baseline Study results.

= (CoolF / ηCool) * %Cool

If unknown, assume 0

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

= 34% for unit in cooled space[109]

= 0% for unit in uncooled space or unknown

ηCool = Efficiency in COP of Cooling equipment

= Actual – If not available, assume 2.8 COP[110]

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	88%[111]

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh_{unit}}{HOURS} * WHFdCool * CF$$

Where:

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

HOURS = Equivalent Full Load Hours as calculated using eShapes loadprofile

Refrigerators = 5280

Freezers = 5895

WHFdCool = Waste heat factor for demand to account for cooling savings from removing waste heat.

Refrigerator Location	WHFdCool
Cooled space	1.22[112]
Uncooled or unknown space	1.0

CF = Coincident factor as calculated using eShapes loadprofile

Refrigerators = 70.9%

Freezers = 95.3%

Deemed approach; Refrigerators

ΔkW = 939.12 /5280 * 1 * 0.709

[109] Based on 123 days where CDD 65>0, divided by 365.25.

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

[111] Based on Dunsky and Opinion Dynamics Baseline Study results.

[112] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour), consistent with the lighting peak hours.

= 0.1261 kW

Deemed approach; Freezers

ΔkW = 811.8 /5895 * 1* 0.953

= 0.1312 kW

NATURAL GAS SAVINGS

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

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

Where:

ΔkWh_{Unit} = kWh savings calculated from either method above, not including the $\Delta kWh_{WasteHeat}$

WHFeHeatGas = Waste Heat Factor for Energy to account for gas heating increase from removing waste heat from refrigerator/freezer

= - (HF / $\eta Heat_{Gas}$) * %GasHeat

If unknown, assume 0

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

= 59% for unit in heated space[113]

= 0% for unit in heated space or unknown

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

=74%[114]

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83%[115]

0.03412 = Converts kWh to Therms

PEAK GAS SAVINGS

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

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings

[113] Based on 217 days where HDD 60>0, divided by 365.25.

[114] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes - based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

[115] Based on Dunsky and Opinion Dynamics Baseline Study results.

is therefore assumed to be:

$$\Delta PeakTherms = \frac{(\Delta Therms)}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[116]

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-APL-RFRC-V04-200101

Sunset Date: 1/1/2022

[116] Number of days where HDD 60 > 0.

2.1.6 Room Air Conditioner

DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets the ENERGY STAR minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard. The minimum efficiency ratings are presented below[117]. Please note that the baseline and default ENERGY STAR levels are based upon the average of available product from the CEC Appliance Database.

<table>
<tr><th>Product Class (Btu/H)</th><th>Federal Standard CEERbase, with louvered sides, without reverse cycle[118]</th><th>Federal Standard CEERbase, without louvered sides, without reverse cycle</th><th>ENERGY STAR CEERee, with louvered sides</th><th>ENERGY STAR CEERee, without louvered sides</th></tr>
<tr><td>< 8,000</td><td>11.0</td><td>10.0</td><td>12.1</td><td>11.0</td></tr>
<tr><td>8,000 to 10,999</td><td rowspan="2">10.9</td><td>9.6</td><td rowspan="2">12.0</td><td>10.6</td></tr>
<tr><td>11,000 to 13,999</td><td>9.5</td><td>10.5</td></tr>
<tr><td>14,000 to 19,999</td><td>10.7</td><td>9.3</td><td>11.8</td><td>10.2</td></tr>
<tr><td>20,000 to 24,999</td><td>9.4</td><td rowspan="3">9.4</td><td rowspan="2">10.3</td><td rowspan="3">10.3</td></tr>
<tr><td>25,000-27,999</td><td rowspan="2">9.0</td></tr>
<tr><td>>=28,000</td><td>9.9</td></tr>
</table>

Casement	Federal Standard CEERbase	ENERGY STAR CEERee
Casement-only	9.5	10.5
Casement-slider	10.4	11.4

Reverse Cycle - Product Class (Btu/H)	Federal Standard CEERbase, with louvered sides	Federal Standard CEERbase, without louvered sides[119]	ENERGY STAR CEERee, with louvered sides[120]	ENERGY STAR CEERee, without louvered sides
< 14,000	N/A	9.3	N/A	10.2
>= 14,000	N/A	8.7	N/A	9.6
< 20,000	9.8	N/A	10.8	N/A
>= 20,000	9.3	N/A	10.2	N/A

[117] Side louvers that extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models. Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size. Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size. Reverse cycle refers to the heating function found in certain room air conditioner models. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf
Note these efficiency levels represent ratings without the Connected Allowance.

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

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR efficiency standards presented above. For default savings, the average efficiency of ENERGY STAR qualified units is used as shown in tables below[121].

DEFINITION OF BASELINE EQUIPMENT

The baseline assumption is a new room air conditioning unit that meets the current minimum federal efficiency standards presented above. The average efficiency of non-ENERGY STAR units is used as shown in tables below:

<table>
<tr><th>Product Class (Btu/H)</th><th>Federal Standard CEERbase, with louvered sides, without reverse cycle</th><th>Federal Standard CEERbase, without louvered sides, without reverse cycle</th><th>ENERGY STAR CEERee, with louvered sides</th><th>ENERGY STAR CEERee, without louvered sides</th></tr>
<tr><td>< 8,000</td><td>11.0</td><td>10.0</td><td>12.1</td><td>11.0</td></tr>
<tr><td>8,000 to 10,999</td><td rowspan="2">11.1</td><td>9.7</td><td rowspan="2">12.0</td><td>10.7</td></tr>
<tr><td>11,000 to 13,999</td><td>9.6</td><td>10.6</td></tr>
<tr><td>14,000 to 19,999</td><td>10.9</td><td>9.3</td><td>11.8</td><td>11.1</td></tr>
<tr><td>20,000 to 24,999</td><td>9.7</td><td rowspan="3">9.6</td><td rowspan="2">10.3</td><td rowspan="3">10.3</td></tr>
<tr><td>25,000-27,999</td><td rowspan="2">9.4</td></tr>
<tr><td>>=28,000</td><td>9.9</td></tr>
</table>

Casement	Federal Standard CEERbase	ENERGY STAR CEERee
Casement-only	9.5	10.5
Casement-slider	10.5	11.4

Reverse Cycle - Product Class (Btu/H)	Federal Standard CEERbase, with louvered sides	Federal Standard CEERbase, without louvered sides	ENERGY STAR CEERee, with louvered sides	ENERGY STAR CEERee, without louvered sides
< 14,000	N/A	9.5	N/A	10.4
>= 14,000	N/A	8.7	N/A	9.6
< 20,000	9.8	N/A	10.8	N/A
>= 20,000	9.3	N/A	10.2	N/A

[121] Based on review of units on the CEC Appliance Database, accessed 03/26/2018. See "Room AC CEC Database_03262018_v3.xls" for more details. Note where no product is available for a particular category, the minimum is used.

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 9 years.[122]

Deemed Measure Cost

The incremental cost for this measure is assumed to be $50 for an ENERGY STAR unit.[123]

Loadshape

Loadshapes RE02 – Residential Multifamily Cooling, and RE07 – Residential Single-Family Cooling

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

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

= dependent on location:

Climate Zone (City based upon)	Hours[124]
5 (Burlington)	330
6 (Mason City)	168
Average/unknown (Des Moines)	292

Btu/H = Size of unit

= Actual. If unknown assume 8500 Btu/hr [125]

CEERbase = Efficiency of baseline unit

= As provided in tables above

CEERee = Efficiency of ENERGY STAR unit

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

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

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

[124] The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008: http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) to FLH for Central Cooling for the same locations (provided by AHRI: see reference file "RoomAC_Calculator")) is 31%. This factor was applied to the ENERGY STAR FLH for Central Cooling provided for Des Moines, IA to provide an assumption for FLH for Room AC, and adjusted by CDD for the other locations.

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

For Example, for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Burlington:

$\Delta kWH_{ENERGY\ STAR}$ = (330 * 8500 * (1/11.1 – 1/12.0)) / 1000

= 19.0 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{Btu/H * \left(\frac{1}{CEERbase * 1.01} - \frac{1}{CEERee * 1.01}\right)}{1000} * CF$$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[126]

1.01 = Factor to convert CEER to EER (CEER includes standby and off power consumption). [127]

Other variables as defined above

For Example, for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Burlington:

$\Delta kW_{ENERGY\ STAR}$ = (8500 * (1/(11.1*1.01) – 1/(12.0*1.01))) / 1000 * 0.3

= 0.017 kW

Natural Gas Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-APL-RMAC-V03-190101

Sunset Date: 1/1/2021

[126] 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)

[127] 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 3.1 Room Air Conditioners Program Requirements'.

2.1.7 Room Air Conditioner Recycling

Description

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The assumed remaining useful life of the existing room air conditioning unit being retired is 4 years[128].

Deemed Measure Cost

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

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Algorithm

Calculation of Savings

Electric Energy Savings

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

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

Where:

Hours = Full Load Hours of room air conditioning unit

Climate Zone (City based upon)	Hours[129]
5 (Burlington)	330

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

[129] The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008: http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) to FLH for Central Cooling for the same locations (provided by AHRI: see reference file "RoomAC_Calculator")) is 31%. This factor was applied to the ENERGY STAR FLH for Central Cooling provided for Des Moines, IA to provide an assumption for FLH

Climate Zone (City based upon)	Hours[129]
6 (Mason City)	168
Average/unknown (Des Moines)	292

BtuH = Average size of rebated unit. Use actual if available – if not, assume 8500[130]

EERexist = Efficiency of recycled unit

= Actual if recorded – If not, assume 9.0[131]

%replaced = Percentage of units dropped off that are replaced

Scenario	%replaced
Customer states unit will not be replaced	0%
Customer states unit will be replaced	100%
Unknown	76%[132]

EERbase = Efficiency of baseline unit

= 10.9[133]

Results using defaults provided above:

Climate Zone (City based upon)	ΔkWh		
	Unit not replaced	Unit replaced	Unknown
5 (Burlington)	311.7	54.3	116.1
6 (Mason City)	158.7	27.7	59.1
Average/Unknown (Des Moines)	275.8	48.1	102.7

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

for Room AC, and adjusted by CDD for the other locations.

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

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

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

133 Minimum Federal Standard for capacity range and most popular class (Without reverse cycle, with louvered sides, and 8,000 to 13,999 Btu/h); http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

CF = Summer Peak Coincidence Factor for measure

= 0.3[134]

Results using defaults provided above:

ΔkW		
Unit not replaced	Unit replaced	Unknown
0.2833	0.0494	0.1055

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RARC-V01-170101

SUNSET DATE: 1/1/2023

[134] 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)

2.1.8 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 non-ENERGY STAR model.

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[135] 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.[136]

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 9 years[137].

Deemed Measure Cost

The incremental cost for this measure is $70.[138]

Loadshape

Loadshape E01 – Flat

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

kWh_{BASE} = Baseline kWh consumption per year[139]

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

= see table below

kWh_{ESTAR} = ENERGY STAR kWh consumption per year[140]

= 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

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5844 hours[141]

CF = Summer Peak Coincidence Factor for measure

= 66.7%[142]

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

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[140] Ibid.

[141] Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator assumption of 16 hours per day (16 * 365.25 = 5844).

[142] Assumes that the purifier usage is evenly spread throughout the year, therefore coincident peak is calculated as 5844/8766 = 66.7%.

DEEMED O&M COST ADJUSTMENT CALCULATION

There are no operation and maintenance cost adjustments for this measure.[143]

MEASURE CODE: RS-APL-AIRP-V01-190101

SUNSET DATE: 1/1/2021

[143] 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.

2.2 Consumer Electronics

2.2.1 Tier 1 Advanced Power Strip (APS)

Description

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

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

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

Definition of Efficient Equipment

The efficient case is the use of a 4-8 plug Tier 1 master controlled 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 programs, 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[144].

Deemed Measure Cost

For time of sale or new construction the incremental cost of a Tier 1 advanced power strip over a standard power strip with surge protection is assumed to be $9[145] ($28 for advanced power strip and $19 for baseline).

For direct install programs the actual full installed cost (including labor) should be used.

Loadshape

Loadshape RE05 – Residential Multifamily Plug Load

Loadshape RE13 – Residential Single-Family Plug Load

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 80%[146].

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[144] This is a consistent assumption with 2.2.2 Advanced Power Strip – Tier 2.

[145] 2016 Price survey performed by Illume Advising LLC, see "Current Surge Protector Costs and Comparison 7-2016" spreadsheet.

[146] 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

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

Where:

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

= 31.0 kWh[147]

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

Installation	$Weighting_{office}$
Home Office	100%
Home Entertainment System	0%
Unknown	41%[148]

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

= 75.1 kWh[149]

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

Installation	$Weighting_{Ent}$
Home Office	0%
Home Entertainment System	100%
Unknown	59%[150]

ISR = In service rate

= 83.2%[151]

Based on defaults provided above the following are the default savings:

ΔkWh_{office} = (31 * 100% + 75.1 * 0%) * 0.832

= 25.8 kWh

ΔkWh_{Ent} = (31 * 0% + 75.1 * 100%) * 0.832

[147] NYSERDA 2011, Advanced Power Strip Research Report. Note that estimates are not based on pre/post metering but on analysis based on frequency and consumption of likely products in active, standby and off modes. This measure should be reviewed frequently to ensure that assumptions continue to be appropriate.
[148] Relative weightings of home office and entertainment systems is based on Navigant, Cadmus, EmPower Maryland Final Evaluation Report – Evaluation Year 4; Residential Retrofit Programs, 2014. If the programs have improved basis for these numbers they should be used.
[149] NYSERDA 2011, Advanced Power Strip Research Report
[150] Relative weightings of home office and entertainment systems is based on Navigant, Cadmus, EmPower Maryland Final Evaluation Report – Evaluation Year 4; Residential Retrofit Programs, 2014. If the programs have improved basis for these numbers they should be used.
[151] Based on Navigant, Cadmus, EmPower Maryland Final Evaluation Report – Evaluation Year 4; Residential Retrofit Programs, 2014. If the programs have improved basis for these numbers they should be used.

= 62.5 kWh

$\Delta kWh_{unknown}$ = (31 * 41% + 75.1 * 59%) * 0.832

= 47.4 kWh

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 Advanced power Strip.

= 7,129 [152]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [153]

ΔkW_{office} = 25.8 / 7129 * 0.8

= 0.0029 kW

ΔkW_{Ent} = 62.5 / 7129 * 0.8

= 0.0070 kW

$\Delta kW_{unknown}$ = 47.4 / 7129 * 0.8

= 0.0053 kW

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-CEL-APS1-V02-180101

SUNSET DATE: 1/1/2020

[152] Average of hours for controlled TV and computer from; NYSERDA Measure Characterization for Advanced Power Strips
[153] In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.

2.2.2 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[154]; both active power loads and standby power loads of controlled devices are managed by Tier 2 AV APS devices. Monitoring and controlling both active and standby power loads of controlled devices will reduce the overall load of a centralized group of electrical equipment (i.e. the home entertainment center). This more intelligent sensing and control process has been demonstrated to deliver increased energy savings and demand reduction compared with 'Tier 1 Advanced Power Strips'.

To date there have been two distinct control strategies to reduce the active AV loads:

1. Infra-red only – this type will begin a count down from the last remote-control signal. Once the set time period is reached without an additional remote signal, there will be a warning (visual and/or audio) to warn the user that the units are about to be switched off. If the user does not then indicate they are still actively using the equipment by using the remote control, the system will switch off.
2. Infra-red and occupancy sensor – in addition to the remote-control signal count down, this system uses motion detection to determine if there is an active user. Only after a set period of no remote-control activity or motion is sensed in the space will a similar warning and ultimate switch off occur.

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. 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. It is therefore recommended that only models that have provided independent evidence to demonstrate an appropriate deemed savings should be eligible, please see Product Classification memo.

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.

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[155].

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).

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[154] 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.

[155] 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.

Deemed Lifetime of Efficient Equipment

The default deemed lifetime value for Tier 2 AV APS is assumed to be 7 years[156].

Deemed Measure Cost

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

Time of Sale: The full cost of a new Tier 2 Advanced Power Strip should be assumed, with a default of $80[157].

Loadshape

Loadshape RE05 – Residential Multifamily Plug Load

Loadshape RE13 – Residential Single-Family Plug Load

Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 80%[158]

Algorithm

Calculation of Energy Savings

Electric Energy Savings

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

Where:

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

Control Strategy	ERP
Infrared Only	40%
Infrared and Occupancy Sensor	25%

$BaselineEnergy_{AV}$ = 454 kWh[159]

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

Control Strategy	ISR
Infrared Only	73%
Infrared and Occupancy Sensor	83%

Based upon default assumptions above, savings are as follows:

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156 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 is proposed, but further evaluation is recommended.

157 Based on internet review of leading manufacturers, 3/2019.

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

159 Weighted average of assumptions derived from AESC, Inc, “Energy Savings of Tier 2 Advanced Power Strips in Residential AC Systems”, p28 and NMR Inc “Advanced Power Strip Metering Study”, October 5 2018, p19. Note that this load represents the average *controlled* AV devices only and will likely be lower than total AC usage.

Control Strategy	ΔkWh
Infrared Only	132.6
Infrared and Occupancy Sensor	94.2

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 [160]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [161]

Based upon default assumptions above, savings are as follows:

Control Strategy	ΔkW
Infrared Only	0.0242
Infrared and Occupancy Sensor	0.0172

Natural Gas Savings

N/A

Peak Gas Savings

N/A

Water and Other Non-Energy Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-CEL-APS2-V04-200101

Sunset Date: 1/1/2023

[160] This is estimate based on assumption that approximately half of savings are during active hours (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.

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

2.3 Hot Water

2.3.1 Gas Water Heater

Description

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

Time of Sale or New Construction:

> The purchase and installation of a new, residential gas-fired storage or tankless water heater meeting program Uniform Energy Factor (UEF) requirements, in place of a storage unit meeting Federal standards.

Early Replacement:

> The early removal of an existing and functioning, residential gas-fired storage or tankless water heater, prior to its natural end of life, and replacement with a new unit meeting program Uniform Energy Factor (UEF) requirements. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.162

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a residential gas-fired storage water heater or tankless water heater meeting ENERGY STAR criteria[163].

Definition of Baseline Equipment

Time of Sale or New Construction: The baseline equipment is assumed to be a new, gas-fired storage residential water heater meeting minimum Federal efficiency standards. For storage water heaters with a storage capacity equal to or less than 55 gallons, the Federal energy factor requirement is calculated as 0.6483 – (0.0017 * storage capacity in gallons) and 0.7897 − (0.0004 × storage capacity in gallons) for greater than 55 gallon storage water heaters.[164]

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 11 years for a gas storage water heater and 20 years for a gas tankless water heater.[165]

For Early Replacement: The remaining life of existing equipment is assumed to be 3.7 for gas storage water heaters

---

[162] If the existing water heater has an Energy Factor (EF) rating and the efficient model has a UEF rating, use the baseline EF and efficient UEF in the below algorithm.

[163] ENERGY STAR Product Specification for Residential Water Heaters, Version 3.2, effective April 16, 2015 https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_1.pdf

[164] Minimum Federal standard as of 4/16/2015; https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8

[165] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

and 6.7 years for gas tankless water heaters.[166]

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. Actual costs may be used if associated baseline costs can also be estimated for the application.

Water Heater Type	Incremental Capital Cost[167]	Full Install Cost[168]
Baseline Storage Unit	N/A	$1,336
Efficient Storage	$320	$1,656
Efficient Tankless	$1,560	$2,896

Early Replacement: Actual full installed costs should be used where available. If actual costs are unavailable, the full installed cost is provided in the table above. The assumed deferred cost (after 4 years) of replacing existing equipment with a new baseline unit is assumed to be $1,336. This cost should be discounted to present value using the utility's discount rate[169].

Loadshape

Loadshape RG07 – Residential Water Heat (gas)

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:

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

Early Replacement:[170]

ΔTherms for remaining life of existing unit (1st 3.7 years for gas storage unit and 1st 6.7 years for gas tankless

[166] Assumes one third of the expected equipment life.

[167] Measure costs based on information from DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.13.

[168] Measure costs based on information from DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.13.

[169] Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.

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

unit):

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

ΔTherms for remaining measure life (next 7.3 years for gas storage unit and next 13.3 years for gas tankless unit):

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

Where:

UEF_{Base} = UEF (efficiency) rating of standard storage water heater according to federal standards[171]

= For gas storage water heaters ≤55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

= For gas storage water heaters >55 gallons: 0.7897 − (0.0004 × storage capacity in gallons)

= If tank size is unknown, assume 0.5633 for a gas storage water heater with a 50-gallon storage capacity

UEF_{EE} = UEF rating of efficient gas water heater.

= Actual or if unknown, assume 0.64 for gas storage water heaters ≤55 gallons, 0.78 for gas storage water heaters >55 gallons, and 0.87 for gas tankless water heaters[172]

$UEF_{Existing}$ = UEF rating for existing gas water heater

= Actual or if unknown, assume 0.52 [173]

GPD = Gallons per day of hot water use per person

= 17.6[174]

Household = Average number of people per household

Household Unit Type	Household [175]
Manufactured	1.96
Single-Family – Deemed	2.12
Multifamily – Deemed	1.4
Custom	Actual Occupancy or Number of Bedrooms[176]

365.25 = Number of days per year

γWater = Specific weight of water

[171] Minimum Federal standard as of 4/16/2015

[172] ENERGY STAR Product Specification for Residential Water Heaters, Version 3.2, effective April 16, 2015 https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_1.pdf

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

[174] Deoreo, B., and P. Mayer. Residential End Uses of Water Study 2013 Update. Water Research Foundation, 2014.

[175] Average household size by building type and water heater fuel type based on the 2007 RASS.

[176] 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.

= 8.33 pounds per gallon

T_{Out} = Tank temperature

= 126.5°F [177]

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

= 56.5°F[178]

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

100,000 = Conversion factor from Btu to therms

> **For example,** a new 50-gallon gas storage water heater installed in a single family home under the Time of Sale program type, using defaults from above, would save:
>
> ΔTherms = (1/0.5633 - 1/0.64) * (17.6 * 2.12 * 365.25 * 8.33 * (126.5 – 56.5) * 1.0) / 100,000
>
> = 16.9 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms/365.25$$

Where:

ΔTherms = Gas savings from installation of efficient water heater

Other variables as defined above

> **For example**, a new 50-gallon gas storage water heater installed in a single family home under the Time of Sale program type, using defaults from above, would save:
>
> ΔPeakTherms = 16.9/365.25
>
> = 0.0463 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-GWHT-V03-190101

SUNSET DATE: 1/1/2022

[177] CPUC Residential Retrofit - High Impact Measure Evaluation Report Draft. Dec. 7, 2009. Pg 76. Average temperature setpoints for two utilities.

[178] Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. http://www.nrel.gov/docs/fy10osti/47246.pdf; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

2.3.2 Heat Pump Water Heaters

Description

This measure characterizes the installation of a heat pump domestic hot water heater in a home. Savings are presented dependent on the heating system installed in the home due to the impact of the heat pump water heater on the heating and cooling loads.

This measure was developed to be applicable to the following program types: TOS, NC, RF[179].

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be an ENERGY STAR Heat Pump domestic water heater[180].

Definition of Baseline Equipment

The baseline condition is a new electric water heater meeting federal minimum efficiency standards[181], dependent on the storage volume (in gallons) of the water heater.

For units ≤55 gallons – resistance storage unit with efficiency: 0.9307 – (0.0002 * rated volume in gallons)

For units >55 gallons – assume a 50 gallon resistance tank baseline i.e. 0.9207 UEF.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 13 years.[182]

Deemed Measure Cost

For Time of Sale or New Construction the incremental installation cost (including labor) should be used. Defaults are provided below[183]. Actual efficient costs can also be used although care should be taken as installation costs can vary significantly due to complexities of a particular site.

For retrofit costs, the actual full installation cost should be used (default provided below if unknown).

Capacity	Efficiency Range	Baseline Installed Cost	Efficient Installed Cost	Incremental Installed Cost
≤55 gallons	<2.6 UEF	$1,032	$2,062	$1,030
	≥2.6 UEF	$1,032	$2,231	$1,199
>55 gallons	<2.6 UEF	$1,319	$2,432	$1,113
	≥2.6 UEF	$1,319	$3,116	$1,797

[179] If the existing water heater has an Energy Factor (EF) rating and the efficient model has a UEF rating, use the baseline EF and efficient UEF in the below algorithm.

[180] If the water heater does not have a UEF rating, but a EF rating, revert to using the previous version of this measure.

[181] Minimum Federal Standard as of 4/1/2015. Medium draw pattern; https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8

[182] DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Chapter 8, Page 8-46.

[183] Costs for <2.6 UEF are based upon averages from the NEEP Phase 3 Incremental Cost Study; http://www.neep.org/incremental-cost-study-phase-3. The assumption for higher efficiency tanks is based upon averaged from NEEP Phase 4 Incremental Cost Study; http://www.neep.org/sites/default/files/resources/NEEP%20Incremental%20Cost%20Study%20FINAL_061016.pdf. See 'HPWH Cost Estimation.xls' for more information.

LOADSHAPE

Loadshape RE12 – Residential Single Family Water Heat

Loadshape RE04 – Residential Multifamily Water Heat

Loadshape RG07 – Residential Water Heat (gas)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{(1/UEF_{BASE} - 1/UEF_{EE}) * GPD * Household * 365.25 * \gamma Water * (TOUT - Tin) * 1.0)}{3412}\right) + kWh_{cool} - kWh_{heat}$$

Where:

UEF$_{BASE}$ = Uniform Energy Factor (efficiency) of standard electric water heater according to federal standards[184]:

For ≤55 gallons: 0.9307 – (0.0002 * rated volume in gallons)

= Default of 0.9207 for a 50 gallon tank a typical sized Residential unit

For >55 gallons: Assume 0.9207 for a 50 gallon tank a typical sized Residential unit

UEF$_{EE}$ = Uniform Energy Factor (efficiency) of Heat Pump water heater.

= Actual

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[185]

= 17.6

Household = Average number of people per household

Household Unit Type	Household [186]
Manufactured	1.96
Single-Family – Deemed	2.12
Multifamily – Deemed	1.4
Custom	Actual Occupancy or Number of Bedrooms[187]

365.25 = Days per year

γWater = Specific weight of water

[184] Minimum Federal Standard as of 1/1/2015.

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

[186] Average household size by building type and water heater fuel type based on the 2007 RASS.

[187] 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.

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= 126.5°F [188]

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

= 56.5[189]

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

3412 = Conversion from Btu to kWh

kWh_cool = Cooling savings from conversion of heat in home to water heat[190]

$$= \left[\frac{\left(\left(1 - \frac{1}{UEF_{EE}}\right) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 34\% * LM}{COP_{COOL} * 3412} \right] * \%Cool$$

Where:

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location[191]

= 0.0 for installation in an unconditioned space

34% = Portion of reduced waste heat that results in cooling savings[192]

COP_{COOL} = COP of Central Air Conditioner

= Actual - If unknown, assume 3.08 (10.5 SEER / 3.412)

LM = Latent multiplier to account for latent cooling demand

= 1.33 [193]

%Cool = Percentage of homes with central cooling

Cooling System	%Cool
Central Air Conditioner	100%
No Central Air Conditioner	0%

188 CPUC Residential Retrofit - High Impact Measure Evaluation Report Draft. Dec. 7, 2009. Pg 76. Average temperature setpoints for two utilities.

189 Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. http://www.nrel.gov/docs/fy10osti/47246.pdf; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

190 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.

191 Note unconditioned means a space that is not intentionally heated via furnace vents or boiler radiators. The presence of and/or leakage from a heating system in a space doesn't in itself imply the space is conditioned.

192 REMRate determined percentage (34%) 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).

193 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

Cooling System	%Cool
Unknown[194]	88%

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

$$= \left(\frac{\left(\left(1 - \frac{1}{UEF_{EE}}\right) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0\right) * LF * 53\%}{COP_{HEAT} * 3412} \right) * \%ElectricHeat$$

Where:

53% = Portion of reduced waste heat that results in increased heating load[195]

COP_{HEAT} = COP of electric heating system

= Actual system efficiency including duct loss - If not available, use[196]:

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

%ElectricHeat = Factor dependent on heating fuel:

Heating System	%ElectricHeat
Electric resistance or heat pump	100%
Gas	0%
Unknown heating fuel[197]	17%

[194] Based on assumption that 64% of homes have central cooling (based on Dunsky and Opinion Dynamics Baseline Study results).
[195] REMRate determined percentage (53%) 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).
[196] 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.
[197] Based on Dunsky and Opinion Dynamics Baseline Study results.

For example, for a 2.0 UEF 50 gallon heat pump water heater in a single family home using default assumptions provided above:

kWh_cool = (((1 - 1/2.0) * 17.6 * 2.12 * 365.25* 8.33 * (126.5 – 56.5) * 1.0 * 0.5 * 0.34 * 1.33) / (3.08 * 3412)) * 0.88

= 75.2 kWh

kWh_heat = (((1 - 1/2.0) * 17.6 * 2.12 * 365.25* 8.33 * (126.5 – 56.5) * 1.0 * 0.5 * 0.53) / (1.38 * 3412)) * 0.17

= 38.0 kWh

ΔkWh = ((1 / 0.9207 – 1 / 2.0) * 17.6 * 2.12 * 365.25 * 8.33 * (126.5 – 56.5)) / 3412 + 75.2 – 38.0

= 1402.3 kWh

Note: whenever using the unknown heating fuel defaults, an additional therm penalty (to account for the percentage of homes with gas heat) should be applied.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

Hours = Full load hours of water heater

= 5186[198]

CF = Summer Peak Coincidence Factor for measure

= 0.33[199]

For example, for a 2.0 UEF 50 gallon heat pump water heater using default assumptions provided above:

ΔkW = 1402.3 / 5186 * 0.33

= 0.0892 kW

NATURAL GAS SAVINGS

$$\Delta Therms = -\left(\frac{\left(\left(1-\frac{1}{\mathrm{UEF_{EE}}}\right) * \mathrm{GPD} * \mathrm{Household} * 365.25 * \gamma\mathrm{Water} * (\mathrm{T_{OUT}} - \mathrm{T_{IN}}) * 1.0\right) * \mathrm{LF} * 53\%}{\eta\mathrm{Heat} * 100{,}000}\right) * \%\mathrm{GasHeat}$$

Where:

ΔTherms = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat[200]

[198] Full load hours assumption based on analysis of loadshape data provided by Cadmus.

[199] 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) / [(annual kWh savings / FLH)] = (0.1 kW) / ((1556 kWh (default assumptions) / 5183 hours) = 0.33.

[200] This is the additional energy consumption required to replace the heat removed from the home during the heating season by the heat pump water heater. The variable kWh_heating (electric resistance) is that additional heating energy for a home with electric resistance heat (COP 1.0). This formula converts the additional heating kWh for an electric resistance home to the MMBtu required in a Natural Gas heated home, applying the relative efficiencies.

0.03412 = conversion factor (therms per kWh)

ηHeat = Efficiency of heating system, i.e., AFUE multiplied by distribution efficiency[201]

= Actual - If not available, use 74%.[202]

%GasHeat = Factor dependent on heating fuel:

Heating System	%GasHeat
Electric resistance or heat pump	0%
Natural Gas	100%
Unknown heating fuel[203]	83%

Other factors as defined above

For example, for a 2.0 UEF 50 gallon heat pump water heater using default assumptions provided above:

ΔTherms = -(((1 - 1/2.0) * 17.6 * 2.12 * 365.25* 8.33 * (126.5 – 56.5) * 1.0 * 0.5 * 0.53) / (0.74 * 100000)) * 0.83

= - 11.8 therms

Peak Gas Savings

Savings for this measure is assumed to be evenly spread across the heating season. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{\mathrm{HeatDays}}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[204]

For example, for a 2.0 UEF 50 gallon heat pump water heater, using default assumptions provided above:

ΔPeakTherms = -11.8 / 217

= - 0.0544 therms

[201] 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.

[202] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey:)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74

[203] Based on Energy Information Administration, 2009 Residential Energy Consumption Survey.

[204] Number of days where HDD 60 >0.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-HPWH-V03-190101

SUNSET DATE: 1/1/2022

2.3.3 Water Heater Temperature Setback

Description

Set point temperatures on hot water systems are often set higher than necessary. Savings are calculated for lowering the set temperature to 120-125 degrees (DOE recommended minimum to prevent Legionella contamination).

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

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

Definition of Efficient Equipment

The high efficiency measure is a hot water tank with the thermostat reduced from its existing temperature to a lower temperature between 120-125 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 is more than one DHW tank 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[205].

Deemed Measure Cost

The incremental cost of a setback is assumed to be $10 for contractor time[206].

Loadshape

Loadshape RE12 – Residential Single Family Water Heat

Loadshape RE04 – Residential Multifamily Water Heat

Loadshape RG07 – Residential Water Heat (gas)

Algorithm

Calculation of Savings

Electric Energy Savings[207]

For homes with electric DHW tanks:

[205] Professional judgment.
[206] Based on labor cost of $40/h and 15min work.
[207] Note this algorithm provides savings only from reduction in standby losses. VEIC 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.

$$\Delta kWh = \frac{(U * A * (Tpre - Tpost) * Hours)}{3412 * RE\_electric}$$

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)

= Actual if know - If unknown, use the table below based on capacity of tank. If capacity unknown, assume 50 gal tank; A = 24.99ft^2.

Capacity (gal)	A (ft^2)[208]
30	19.16
40	23.18
50	24.99
80	31.84

Tpre = Actual hot water setpoint prior to adjustment. If unknown, assume 135 degrees

Tpost = Actual new hot water setpoint, which may not be lower than 120 degrees. If unknown, assume 120 degrees.

Hours = Number of hours in a year (since savings are assumed to be constant over year

= 8766

3412 = Conversion from Btu to kWh

RE_electric = Recovery efficiency of electric hot water heater

= 0.98 [209]

A deemed savings assumption for single family homes, where site-specific inputs are not available, would be as follows:

ΔkWh = (0.083 * 24.99 * (135 – 120) * 8766) / (3412 * 0.98)

= 81.6 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

Hours = 8766

CF = Summer Peak Coincidence Factor for measure

= 1

[208] Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual; (http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx). Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

[209] Electric water heaters have recovery efficiency of 98%: https://www.ahridirectory.org/Search/SearchHome

A deemed savings assumption, where site-specific inputs are not available, would be as follows:

ΔkW = (81.6/ 8766) * 1

= 0.0093 kW

NATURAL GAS SAVINGS

For homes with gas water heaters:

$$\Delta Therms = \frac{U * A * (Tpre - Tpost) * Hours}{100{,}000 * RE\_gas}$$

Where

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

RE_gas = Recovery efficiency of gas water heater

= Actual if known - if not, assume:

= 78% For SF homes[210]

= 60% For MF homes with DHW from central boiler

= 78% for MF homes with dedicated gas DHW system

A deemed savings assumption, where site-specific inputs are not available, would be as follows:

For Single Family homes or multifamily homes with dedicated gas DHW system:

ΔTherms = (0.083 * 24.99 * (135 – 120) * 8766) / (100,000 * 0.78)

= 3.5 Therms

An example for multifamily homes with DHW from a central boiler is provided below (tank capacity can vary considerably so actual values should be used). This example assumes a 119 gallon tank with a surface area of 47.80ft^2:

ΔTherms = (0.083 * 47.80 * (135 – 120) * 8766) / (100,000 * 0.60)

= 8.7 Therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Water Heating

= 0.002952 for Residential Water Heating

A deemed savings assumption, where site-specific inputs are not available, would be as follows:

For Single Family homes or multifamily homes with dedicated gas DHW system:

[210] 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%.

ΔPeakTherms = 3.5 * 0.002952

= 0.0103 Therms

An example for multifamily homes with DHW from a central boiler is provided below (tank capacity can vary considerably so actual values should be used). This example assumes a 119 gallon tank with a surface area of 47.80ft^2:

ΔPeakTherms = 8.7 * 0.002952

= 0.0257 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-TMPS-V01-170101

SUNSET DATE: 1/1/2023

2.3.4 Low Flow Faucet Aerators

Description

This measure relates to the installation of a low flow faucet aerator in a single family home or multifamily unit in unit kitchen or bathroom faucet fixture.

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, rated at 1.5 gallons per minute (GPM) [211] 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 faucet aerator rated at 2.2 GPM[212] or greater.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years.[213]

Deemed Measure Cost

For RF and DI, the incremental cost for this measure is $16[214] or program actual.

For TOS and NC, the incremental cost is $0.[215]

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

Loadshape

Loadshape RE12 – Residential Single Family Water Heat

Loadshape RE04 – Residential Multifamily Water Heat

Loadshape RG07 – Residential Water Heat (gas)

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[211] IPL program product data for 2014 Iowa Residential Energy Assessments.

[212] DOE Energy Cost Calculator for Faucets and Showerheads: (http://www1.eere.energy.gov/femp/technologies/eep_faucets_showerheads_calc.html#output)

[213] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation," California Public Utilities Commission, January, 2014. "

[214] Direct-install price per faucet assumes cost of aerator and install time. (2011, Market research average of $3 and assess and install time of $13(20min @ $40/hr).

[215] Based on VEIC's market research of the lower 10th percentile of product categories, which is assumed to filter out price differences related to product quality and features, the incremental cost difference between a baseline and low-flow aerator is negligible.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[216] (unless faucet type is unknown, then it is per household).

$$\Delta kWh = \%ElectricDHW * ((GPM\_base - GPM\_low) * L * Household * 365.25 * \frac{DF}{FPH}) * EPG\_electric * ISR$$

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	30%[217]

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used"

= Measured full throttle flow * 0.83 throttling factor[218]

If flow not measured, assume (2.2 * 0.83) = 1.83 GPM

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

= Rated full throttle flow * 0.95 throttling factor[219]

If flow not available, assume (1.5 * 0.95) = 1.43 GPM

L = Average 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 (min/person/day)
Kitchen	4.5[220]
Bathroom	1.6[221]
If location unknown (total for	9.0[222]

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

[217] Default assumption for unknown fuel is based on on Dunsky and Opinion Dynamics Baseline Study results. 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

[218] 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

[219] 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

[220] 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.

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

[222] One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd, Illinois residential survey of 140 sites, provided by Cadmus.

Faucet Type	L (min/person/day)
household): Single-Family	
If location unknown (total for household): Multifamily	6.9[223]

Household = Average number of people per household

Household Unit Type	Household[224]
Single-Family - Deemed	2.51
Multifamily - Deemed	2.18
Custom	Actual Occupancy or Number of Bedrooms[225]

365.25 = Days in a year, on average

DF = Drain Factor

Faucet Type	Drain Factor[226]
Kitchen	75%
Bath	90%
Unknown	79.5%

FPH = Faucets Per Household

Faucet Type	FPH
Kitchen or Bathroom (i.e. divide by one since use assumption is per faucet)	1
If location unknown (total for household): Single-Family	3.83
If location unknown (total for household): Multifamily	2.5

EPG_electric = Energy per gallon of water used by faucet supplied by electric water heater

= (γWater * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

= 0.0735 kWh/gal (Bath), 0.0909 kWh/gal (Kitchen), 0.0859 kWh/gal (Unknown) if resistance tank (or unknown)

= 0.0360 kWh/gal (Bath), 0.0446 kWh/gal (Kitchen), 0.0421 kWh/gal (Unknown) if heat

[223] One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd, Illinois residential survey of 140 sites, provided by Cadmus.

[224] Average household size from U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates for Iowa (Table DP04). Single-family household size based on owner-occupied estimate and multifamily household size based on renter-occupied estimate.

[225] 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.

[226] 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.

pump water heater

Where:

γWater = Specific weight of water (lbs/gallon)

= 8.33 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[227]

SupplyTemp = Assumed temperature of water entering house

= 56.5[228]

RE_electric = Average Recovery efficiency of electric water heater

= 98% [229] for electric resistance (or unknown)

= 200%[230] for heat pump water heaters

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators

Program		ISR
Direct-install, NC, or TOS		0.95[231]
Efficiency Kits – EnergyWise (Low Income) [232]	Kitchen	0.74
	Bathroom	0.70
	Unknown	0.72
Efficiency Kits – LivingWise (Schools)[233]		0.43

Based on defaults provided above:

Program	Faucet	Market/Program	Algorithm	ΔkWh
Direct-install, NC, or TOS	Kitchen	Single Family Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0909 * 0.95	106.9
		Single Family Heat	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 /	52.4

[227] 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 91F 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.

[228] Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. http://www.nrel.gov/docs/fy10osti/47246.pdf; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

[229] Electric water heaters have recovery efficiency of 98%: https://www.ahridirectory.org/Search/SearchHome

[230] 200% represents a reasonable estimate of the weighted average event recovery efficiency for heat pump water heaters, including those that are set to Heat Pump only mode (and so have a recovery efficiency >250%) and those that are set in hybrid mode where a larger draw would kick the unit in to resistance mode (98%), or where low total water consumption can result in lower COPs due to relatively high standby losses. Note that the AHRI directory provides recovery efficiency ratings, some of which are >250% but most are rated at 100%. This is due to the rating test involving a large hot water draw, consistent with multiple showers.

[231] 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.

[232] Based on Cadmus, "Final Report: Iowa 2015 Energy Wise Program", January 29, 2016, p16.. Unknown is average of kitchen and bathroom installations.

[233] Based on results provided in "School-based interim process memo_Final_100215.doc".

Program	Faucet	Market/Program	Algorithm	ΔkWh
		Pump DHW	1) * 0.0446 * 0.95	
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0909 * 0.95	32.1
		Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0909 * 0.95	92.8
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0446 * 0.95	45.5
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0909 * 0.95	27.8
	Bathroom	Single Family Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0735 * 0.95	36.9
		Single Family Heat Pump DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0360 * 0.95	18.1
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0735 * 0.95	11.1
		Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0735 * 0.95	32.0
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0360 * 0.95	15.7
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0735 * 0.95	9.6
	Unknown	Single Family Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.0859 * 0.95	55.9
		Single Family Heat Pump DHW	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.0421 * 0.95	27.4
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795/ 3.83) * 0.0859 * 0.95	16.8
		Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0859 * 0.95	57.0
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0421 * 0.95	28.0
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0859 * 0.95	17.1
		Unknown Location	Assumes 80% SF and 20% MF[234]	16.8
Efficiency Kits – EnergyWise (Low Income)	Kitchen	Single Family Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0909 * 0.74	83.3
		Single Family Heat Pump DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0446 * 0.74	40.8
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0909 * 0.74	25.0
		Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0909 * 0.74	72.3
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0446 * 0.74	35.5
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0909 * 0.74	21.7
	Bathroom	Single Family Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0735 * 0.70	27.2

234 Based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IA, see “HC2.9 Structural and Geographic in Midwest Region.xls”.

Program	Faucet	Market/Program	Algorithm	ΔkWh
		Single Family Heat Pump DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0360 * 0.70	13.3
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0735 * 0.70	8.2
		Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0735 * 0.70	23.6
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0360 * 0.70	11.6
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0735 * 0.70	7.1
	Unknown	Single Family Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.0859 * 0.72	42.4
		Single Family Heat Pump DHW	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.0421 * 0.72	20.8
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795/ 3.83) * 0.0859 * 0.72	12.7
		Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0859 * 0.72	43.2
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0421 * 0.72	21.2
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0859 * 0.72	13.0
		Unknown Location	Assumes 80% SF and 20% MF[235]	12.8
Efficiency Kits – LivingWise (Schools)	Kitchen	Single Family Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0909 * 0.43	48.4
		Single Family Heat Pump DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0446 * 0.43	23.7
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0909 * 0.43	14.5
		Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0909 * 0.43	42.0
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0446 * 0.43	20.6
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0909 * 0.43	12.6
	Bathroom	Single Family Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0735 * 0.43	16.7
		Single Family Heat Pump DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0360 * 0.43	8.2
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0735 * 0.43	5.0
		Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0735 * 0.43	14.5
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0360 * 0.43	7.1
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0735 * 0.43	4.3
		Single Family Electric	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795	25.3

[235] Based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IA, see “HC2.9 Structural and Geographic in Midwest Region.xls”.

Program	Faucet	Market/Program	Algorithm	ΔkWh
		Resistance DHW	/ 3.83) * 0.0859 * 0.43	
		Single Family Heat Pump DHW	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.0421 * 0.43	12.4
		Single Family Unknown DHW	= 0.3 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795/ 3.83) * 0.0859 * 0.43	7.6
	Unknown	Multifamily Electric Resistance DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0859 * 0.43	25.8
		Multifamily Heat Pump DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0421 * 0.43	12.7
		Multifamily Unknown DHW	= 0.3 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0859 * 0.43	7.7
		Unknown Location	Assumes 80% SF and 20% MF[236]	7.6

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for faucet use per faucet

= (GPM_base * L * Household/FPH * 365.25 * DF * 0.479[237])/ GPH

Building Type	Faucet location	Calculation	Hours per faucet
Single Family Electric Resistance DHW (or unknown)	Kitchen	(1.83 * 4.5 * 2.51/1 * 365.25 * 0.75 * 0.479) / 25.8	105.1
	Bathroom	(1.83 * 1.6 * 2.51/1 * 365.25 * 0.9 * 0.479) / 25.8	44.9
	Unknown	(1.83 * 9.0 * 2.51/3.83 * 365.25 * 0.795 * 0.479) / 25.8	58.2
Single Family Heat Pump DHW	Kitchen	(1.83 * 4.5 * 2.51/1 * 365.25 * 0.75 * 0.479) / 52.7	51.5
	Bathroom	(1.83 * 1.6 * 2.51/1 * 365.25 * 0.9 * 0.479) / 52.7	22.0
	Unknown	(1.83 * 9.0 * 2.51/3.83 * 365.25 * 0.795 * 0.479) / 52.7	28.5
Multifamily Electric Resistance DHW (or unknown)	Kitchen	(1.83 * 4.5 * 2.18/1 * 365.25 * 0.75 * 0.479) / 25.8	91.3
	Bathroom	(1.83 * 1.6 * 2.18/1 * 365.25 * 0.9 * 0.479) / 25.8	39.0
	Unknown	(1.83 * 6.9 * 2.18/2.5 * 365.25 * 0.795 * 0.479)/ 25.8	59.4
Multifamily Heat Pump DHW	Kitchen	(1.83 * 4.5 * 2.18/1 * 365.25 * 0.75 * 0.479) / 52.7	44.7
	Bathroom	(1.83 * 1.6 * 2.18/1 * 365.25 * 0.9 * 0.479) / 52.7	19.1

[236] Based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IA, see "HC2.9 Structural and Geographic in Midwest Region.xls".
[237] 47.9% is the proportion of hot 126.5F water mixed with 56.5F supply water to give 90F mixed faucet water.

Building Type	Faucet location	Calculation	Hours per faucet
	Unknown	(1.83 * 6.9 * 2.18/2.5 * 365.25 * 0.795 * 0.479)/ 52.7	29.1

GPH = Gallons per hour recovery of electric water heater calculated for 70F temp rise (126.5-56.5), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 4.5kW electric resistance storage tank

= 25.8 for electric resistance or unknown, 52.7 for heat pump[238]

CF = Coincidence Factor for electric load reduction

= 0.017[239]

Based on defaults provided above:

Program	Faucet	Market/Program	Algorithm	ΔkW
Direct-install, NC, or TOS	Kitchen	Single Family Electric Resistance DHW	= 106.3/105.1 * 0.017	0.0172
		Single Family Heat Pump DHW	= 52.4/51.5 * 0.017	0.0173
		Single Family Unknown DHW	= 32.1/105.1 * 0.017	0.0052
		Multifamily Electric Resistance DHW	= 92.8/91.3 * 0.017	0.0173
		Multifamily Heat Pump DHW	= 45.5/44.7 * 0.017	0.0173
		Multifamily Unknown DHW	= 27.8/91.3* 0.017	0.0052
	Bathroom	Single Family Electric Resistance DHW	= 36.9/44.9 * 0.017	0.0140
		Single Family Heat Pump DHW	= 18.1/22.0 * 0.017	0.0140
		Single Family Unknown DHW	= 11.1/44.9 * 0.017	0.0042
		Multifamily Electric Resistance DHW	= 32.0/39.0 * 0.017	0.0139
		Multifamily Heat Pump DHW	= 15.7/19.1 * 0.017	0.0140
		Multifamily Unknown DHW	= 9.6/39.0 * 0.017	0.0042
	Unknown	Single Family Electric Resistance DHW	= 55.9/58.2 * 0.017	0.0163
		Single Family Heat Pump DHW	= 27.4/28.5 * 0.017	0.0163
		Single Family Unknown DHW	= 16.8/58.2 * 0.017	0.0049
		Multifamily Electric Resistance DHW	= 57.0/59.4 * 0.017	0.0163
		Multifamily Heat Pump DHW	= 28.0/29.1 * 0.017	0.0164
		Multifamily Unknown DHW	= 17.1/59.4 * 0.017	0.0049
		Unknown	Assumes 80% SF and 20% MF	0.0076
Efficiency Kits – EnergyWise (Low Income)	Kitchen	Single Family Electric Resistance DHW	= 83.3/105.1 * 0.017	0.0135
		Single Family Heat Pump DHW	= 40.8/51.5 * 0.017	0.0135
		Single Family Unknown DHW	= 25.0/105.1 * 0.017	0.0040
		Multifamily Electric Resistance DHW	= 72.3/91.3 * 0.017	0.0135
		Multifamily Heat Pump DHW	= 35.5/44.7 * 0.017	0.0135
		Multifamily Unknown DHW	= 21.7/91.3 * 0.017	0.0040
	Bathroom	Single Family Electric Resistance DHW	= 27.2/44.9* 0.017	0.0103
		Single Family Heat Pump DHW	= 13.3/22.0* 0.017	0.0103

[238] See 'Calculation of GPH Recovery_03282018.xls' for calculation details.

[239] Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Deoreo, B., and P. Mayer. "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*65/365.25 = 3.20%. The number of hours of recovery during peak periods is therefore assumed to be 3.20% *142 = 4.5 hours of recovery during peak period, where 142 equals the average annual electric DHW recovery hours for faucet use in SF homes. There are 260 hours in the peak period, so the probability you will see savings during the peak period is 4.5/260 = 0.017.

Program	Faucet	Market/Program	Algorithm	ΔkW
		Single Family Unknown DHW	= 8.2/44.9* 0.017	0.0031
		Multifamily Electric Resistance DHW	= 23.6/39.0 * 0.017	0.0103
		Multifamily Heat Pump DHW	= 11.6/19.1 * 0.017	0.0103
		Multifamily Unknown DHW	= 7.1/39.0 * 0.017	0.0031
	Unknown	Single Family Electric Resistance DHW	= 42.4/58.2 * 0.017	0.0124
		Single Family Heat Pump DHW	= 20.8/28.5 * 0.017	0.0124
		Single Family Unknown DHW	= 12.7/58.2 * 0.017	0.0037
		Multifamily Electric Resistance DHW	= 43.2/59.4 * 0.017	0.0124
		Multifamily Heat Pump DHW	= 21.2/29.1 * 0.017	0.0124
		Multifamily Unknown DHW	= 13.0/59.4 * 0.017	0.0037
		Unknown	Assumes 80% SF and 20% MF	0.0037
Efficiency Kits – LivingWise (Schools)	Kitchen	Single Family Electric Resistance DHW	= 48.4/105.1 * 0.017	0.0078
		Single Family Heat Pump DHW	= 23.7/51.5 * 0.017	0.0078
		Single Family Unknown DHW	= 14.5/105.1 * 0.017	0.0023
		Multifamily Electric Resistance DHW	= 42.0/91.3 * 0.017	0.0078
		Multifamily Heat Pump DHW	= 20.6/44.7 * 0.017	0.0078
		Multifamily Unknown DHW	= 12.6/91.3 * 0.017	0.0023
	Bathroom	Single Family Electric Resistance DHW	= 16.7/44.9* 0.017	0.0063
		Single Family Heat Pump DHW	= 8.2/22.0* 0.017	0.0063
		Single Family Unknown DHW	= 5.0/44.9* 0.017	0.0019
		Multifamily Electric Resistance DHW	= 14.5/39.0 * 0.017	0.0063
		Multifamily Heat Pump DHW	= 7.1/19.1 * 0.017	0.0064
		Multifamily Unknown DHW	= 4.3/39.0 * 0.017	0.0019
	Unknown	Single Family Electric Resistance DHW	= 25.3/58.2 * 0.017	0.0074
		Single Family Heat Pump DHW	= 12.4/28.5 * 0.017	0.0074
		Single Family Unknown DHW	= 7.6/58.2 * 0.017	0.0022
		Multifamily Electric Resistance DHW	= 25.8/59.4 * 0.017	0.0074
		Multifamily Heat Pump DHW	= 12.7/29.1 * 0.017	0.0074
		Multifamily Unknown DHW	= 7.7/59.4 * 0.017	0.0022
		Unknown	Assumes 80% SF and 20% MF	0.0022

NATURAL GAS SAVINGS

$$\Delta Therms = \%FossilDHW * (GPM\_base - GPM\_low) * L * Household * 365.25 * \frac{DF}{FPH} * EPG\_gas * ISR$$

Where:

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

DHW fuel	%ElectricDHW
Electric	0%
Natural Gas	100%
Unknown	70%[240]

[240] Default assumption for unknown fuel is based on Dunsky and Opinion Dynamics Baseline Study results. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

EPG_gas = Energy per gallon of hot water supplied by gas

= (γWater * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.0032 Therm/gal for SF or MF homes with storage tank (Bath), 0.0039 Therm/gal for SF or MF homes with storage tank (Kitchen), 0.0037 Therm/gal for SF or MF homes with storage tank (Unknown)

= 0.0042 Therm/gal for MF homes with central boiler DHW (Bath), 0.0052 Therm/gal for MF homes with central boiler DHW (Kitchen), 0.0049 Therm/gal for MF homes with central boiler DHW (Unknown)

= 0.0036 Therm/gal for MF homes with unknown DHW (Bath), 0.0044 Therm/gal for MF homes with unknown DHW (Kitchen), 0.0042 Therm/gal for MF homes with unknown DHW (Unknown)

Where:

RE_gas = Recovery efficiency of gas water heater

= 78% for SF homes[241]

= 78% for MF homes with storage tank, 59% if hot water through central boiler or 69% if unknown[242]

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

Other variables as defined above

Program	Faucet	Market/Program	Algorithm	ΔTherms
Direct-install, NC, or TOS	Kitchen	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0039 * 0.95	4.6
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0039 * 0.95	3.2
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0039 * 0.95	4.0
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0052 * 0.95	5.3
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0044 * 0.95	4.5
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0044 * 0.95	3.1
	Bathroom	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0032 * 0.95	1.6
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0032 * 0.95	1.1
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0032 * 0.95	1.4

[241] 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%.

[242] Water heating in multi-family buildings is often provided by a larger central boiler. An average efficiency of 0.69 is used for this analysis as a default for multi-family buildings where water heating system is unknown.

Program	Faucet	Market/Program	Algorithm	ΔTherms
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0042 * 0.95	1.8
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0036 * 0.95	1.6
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0036 * 0.95	1.1
	Unknown	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.0037 * 0.95	2.4
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795/ 3.83) * 0.0037 * 0.95	1.7
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0037 * 0.95	2.5
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0049 * 0.95	3.3
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0042 * 0.95	2.8
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0042 * 0.95	2.0
		Unknown Location	Assumes 80% SF and 20% MF	1.7
Efficiency Kits – EnergyWise (Low Income)	Kitchen	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0039 * 0.74	3.6
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0039 * 0.74	2.5
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0039 * 0.74	3.1
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0052 * 0.74	4.1
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0044 * 0.74	3.5
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0044 * 0.74	2.4
	Bathroom	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0032 * 0.70	1.2
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0032 * 0.70	0.8
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0032 * 0.70	1.0
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0042 * 0.70	1.3
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0036 * 0.70	1.2
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0036 * 0.70	0.8
	Unknown	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.0037 * 0.72	1.8
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795/ 3.83) * 0.0037 * 0.72	1.3
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0037 * 0.72	1.9

Program	Faucet	Market/Program	Algorithm	ΔTherms
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0049 * 0.72	2.5
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0042 * 0.72	2.1
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0042 * 0.72	1.5
		Unknown Location	Assumes 80% SF and 20% MF	1.4
Efficiency Kits – LivingWise (Schools)	Kitchen	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0039 * 0.43	2.1
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.0039 * 0.43	1.5
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0039 * 0.43	1.8
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0052 * 0.43	2.4
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0044 * 0.43	2.0
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.0044 * 0.43	1.4
	Bathroom	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0032 * 0.43	0.7
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.0032 * 0.43	0.5
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0032 * 0.43	0.6
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0042 * 0.43	0.8
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0036 * 0.43	0.7
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.0036 * 0.43	0.5
	Unknown	Single Family Gas DHW	= 1 * ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.0037 * 0.43	1.1
		Single Family Unknown DHW	= 0.70 * ((1.83 – 1.43) * 9.0 * 2.51* 365.25 * 0.795/ 3.83) * 0.0037 * 0.43	0.8
		Multifamily Gas Storage DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0037 * 0.43	1.1
		Multifamily Gas Central Boiler DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0049 * 0.43	1.5
		Multifamily Gas Unknown DHW	= 1 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0042 * 0.43	1.3
		Multifamily Unknown DHW	= 0.70 * ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.0042 * 0.43	0.9
		Unknown Location	Assumes 80% SF and 20% MF	0.9

Peak Gas Savings

Savings for this measure are assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{365.25}$$

Where:

ΔTherms = Therm impact calculated above

365.25 = Days per year

Program	Faucet	Market/Program	ΔPeakTherms
Direct-install, NC, or TOS	Kitchen	Single Family Gas DHW	0.0126
		Single Family Unknown DHW	0.0088
		Multifamily Gas Storage DHW	0.0110
		Multifamily Gas Central Boiler DHW	0.0145
		Multifamily Gas Unknown DHW	0.0123
		Multifamily Unknown DHW	0.0085
	Bathroom	Single Family Gas DHW	0.0044
		Single Family Unknown DHW	0.0030
		Multifamily Gas Storage DHW	0.0038
		Multifamily Gas Central Boiler DHW	0.0049
		Multifamily Gas Unknown DHW	0.0044
		Multifamily Unknown DHW	0.0030
	Unknown	Single Family Gas DHW	0.0066
		Single Family Unknown DHW	0.0047
		Multifamily Gas DHW	0.0068
		Multifamily Gas Central Boiler DHW	0.0090
		Multifamily Gas Unknown DHW	0.0077
		Multifamily Unknown DHW	0.0055
		Unknown Location	0.0047
Efficiency Kits – EnergyWise (Low Income)	Kitchen	Single Family Gas DHW	0.0099
		Single Family Unknown DHW	0.0068
		Multifamily Gas Storage DHW	0.0085
		Multifamily Gas Central Boiler DHW	0.0112
		Multifamily Gas Unknown DHW	0.0096
		Multifamily Unknown DHW	0.0066
	Bathroom	Single Family Gas DHW	0.0033
		Single Family Unknown DHW	0.0022
		Multifamily Gas Storage DHW	0.0027
		Multifamily Gas Central Boiler DHW	0.0036
		Multifamily Gas Unknown DHW	0.0033
		Multifamily Unknown DHW	0.0022
	Unknown	Single Family Gas DHW	0.0049
		Single Family Unknown DHW	0.0036
		Multifamily Gas DHW	0.0052
		Multifamily Gas Central Boiler DHW	0.0068
		Multifamily Gas Unknown DHW	0.0057
		Multifamily Unknown DHW	0.0041
		Unknown Location	0.0038
Efficiency Kits – LivingWise (Schools)	Kitchen	Single Family Gas DHW	0.0057
		Single Family Unknown DHW	0.0041
		Multifamily Gas Storage DHW	0.0049
		Multifamily Gas Central Boiler DHW	0.0066
		Multifamily Gas Unknown DHW	0.0055

Program	Faucet	Market/Program	ΔPeakTherms
		Multifamily Unknown DHW	0.0038
	Bathroom	Single Family Gas DHW	0.0019
		Single Family Unknown DHW	0.0014
		Multifamily Gas Storage DHW	0.0016
		Multifamily Gas Central Boiler DHW	0.0022
		Multifamily Gas Unknown DHW	0.0019
		Multifamily Unknown DHW	0.0014
	Unknown	Single Family Gas DHW	0.0030
		Single Family Unknown DHW	0.0022
		Multifamily Gas DHW	0.0030
		Multifamily Gas Central Boiler DHW	0.0041
		Multifamily Gas Unknown DHW	0.0036
		Multifamily Unknown DHW	0.0025
		Unknown Location	0.0025

Water Impact Descriptions and Calculation

$$\Delta Gallons = ((GPM\_base - GPM\_low) * L * Household * 365.25 * \frac{DF}{FPH}) * ISR$$

Variables as defined above

Program	Faucet	Market/Program	Algorithm	ΔGallons
Direct-install, NC, or TOS	Kitchen	Single Family	= ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.95	1,176
		Multifamily	= ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.95	1,021
	Bathroom	Single Family	= ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.95	502
		Multifamily	= ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.95	436
	Unknown	Single Family	= ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.95	651
		Multifamily	= ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.95	664
		Unknown Location	Assumes 80% SF and 20% MF	653
Efficiency Kits – EnergyWise (Low Income)	Kitchen	Single Family	= ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.74	916
		Multifamily	= ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.74	795
	Bathroom	Single Family	= ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.70	370
		Multifamily	= ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.70	321
	Unknown	Single Family	= ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.72	493
		Multifamily	= ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.72	503
		Unknown Location	Assumes 80% SF and 20% MF	495
Efficiency Kits – LivingWise (Schools)	Kitchen	Single Family	= ((1.83 – 1.43) * 4.5 * 2.51 * 365.25 * 0.75 / 1) * 0.43	532
		Multifamily	= ((1.83 – 1.43) * 4.5 * 2.18 * 365.25 * 0.75 / 1) * 0.43	462
	Bathroom	Single Family	= ((1.83 – 1.43) * 1.6 * 2.51 * 365.25 * 0.90 / 1) * 0.43	227
		Multifamily	= ((1.83 – 1.43) * 1.6 * 2.18 * 365.25 * 0.90 / 1) * 0.43	197
	Unknown	Single Family	= ((1.83 – 1.43) * 9.0 * 2.51 * 365.25 * 0.795 / 3.83) * 0.43	295
		Multifamily	= ((1.83 – 1.43) * 6.9 * 2.18 * 365.25 * 0.795/ 2.5) * 0.43	301
		Unknown Location	Assumes 80% SF and 20% MF	296

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-LFFA-V04-200101

SUNSET DATE: 1/1/2023

2.3.5 Low Flow Showerheads

Description

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

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

To qualify for this measure, the installed equipment must be a low flow showerhead rated at 1.5 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 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.[243]

Deemed Measure Cost

For direct install programs, actual full installed costs should be used where available. If actual costs are unavailable, assume a full installed cost of $42.22.[244]

For time of sale or new construction, actual incremental costs may be used (assume a baseline showerhead material cost of $14.32).[245] If actual costs are unavailable, assume an incremental cost of $14.90.[246]

For low flow showerheads provided in Efficiency Kits, the actual program delivery costs should be used.

Loadshape

Loadshape RE12 – Residential Single Family Water Heat

Loadshape RE04 – Residential Multifamily Water Heat

Loadshape RG07 – Residential Water Heat (gas)

[243] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation,” California Public Utilities Commission, January, 2014. "

[244] Direct-install price per showerhead assumes cost of showerhead ($29.22 from the California DEER Ex Ante Database) and install time of $13 (20min @ $40/hr).

[245] Cost of standard showerhead from California DEER Ex Ante Database.

[246] Incremental cost from California DEER Ex Ante Database.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note: these savings are per showerhead fixture

$$\Delta kWh = \%ElectricDHW * (GPM\_base - GPM\_low) * L * Household * SPCD * \frac{365.25}{SPH} * EPG\_electric * ISR$$

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	30%[247]

GPM_base = Flow rate of the baseline showerhead

= Actual measured flow rate. If not measured assume:

Program	GPM_base
Direct-install	2.5 [248]
Retrofit, Efficiency Kits, NC, or TOS	2.35[249]

GPM_low = Flow rate of the low-flow showerhead:

= Actual measured flow rate. If not measured, assume 1.5GPM

L = Shower length in minutes with showerhead

= 7.8 min[250]

Household = Average number of people per household

Household Unit Type	Household[251]
Single-Family - Deemed	2.51
Multifamily - Deemed	2.18

[247] Default assumption for unknown fuel is based on Dunsky and Opinion Dynamics Baseline Study results. 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

[248] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

[249] 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.

[250] 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.

[251] Average household size from U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates for Iowa (Table DP04). Single-family household size based on owner-occupied estimate and multifamily household size based on renter-occupied estimate. .

Household Unit Type	Household[251]
Custom	Actual Occupancy or Number of Bedrooms[252]

SPCD = Showers Per Capita Per Day

= 0.6[253]

365.25 = Days per year, on average

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

Household Unit Type	SPH
Single-Family	1.79[254]
Multifamily	1.3[255]
Custom	Actual

EPG_electric = Energy per gallon of hot water supplied by electric

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

= 0.1109 kWh/gal for resistance (or unknown) unit, 0.0543 kWh/gal for heat pump water heaters

Where:

γWater = Specific weight of water (lbs/gallon)

= 8.33 lbs/gallon

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

ShowerTemp = Assumed temperature of water

= 101F [256]

SupplyTemp = Assumed temperature of water entering house

= 56.5[257]

RE_electric = Average Recovery efficiency of electric water heater

= 98% [258] for electric resistance (or unknown)

= 200%[259] for heat pump water heaters

[252] 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.

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

[254] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

[255] 2009 ComEd residential survey of 140 sites, provided by Cadmus.

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

[257] Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. http://www.nrel.gov/docs/fy10osti/47246.pdf; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

[258] Electric water heaters have recovery efficiency of 98%: https://www.ahridirectory.org/Search/SearchHome

[259] 200% represents a reasonable estimate of the weighted average event recovery efficiency for heat pump water heaters, including those that are set to Heat Pump only mode (and so have a recovery efficiency >250%) and those that are set in hybrid

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of showerhead

Program	ISR
Direct-install, NC, or TOS	0.98[260]
Efficiency Kits – EnergyWise (Low Income) [261]	0.74
Efficiency Kits – LivingWise (Schools)[262]	0.43

Based on defaults provided above:

Program	Market	Algorithm	ΔkWh
Direct Install	Single Family Electric Resistance DHW	= 1.0 * ((2.5 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.111 * 0.98	260.7
	Single Family Heat Pump DHW	= 1.0 * ((2.5 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.0543 * 0.98	127.6
	Single Family Unknown DHW	= 0.30 * ((2.5 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.111 * 0.98	78.2
	Multifamily Electric Resistance DHW	= 1.0 * ((2.5 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.111 * 0.98	311.8
	Multifamily Heat Pump DHW	= 1.0 * ((2.5 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.0543 * 0.98	152.5
	Multifamily Unknown DHW	= 0.30 * ((2.5 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.111 * 0.98	93.5
NC or TOS	Single Family Electric Resistance DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.111 * 0.98	221.6
	Single Family Heat Pump DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.0543 * 0.98	108.4
	Single Family Unknown DHW	= 0.30 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.111 * 0.98	66.5
	Multifamily Electric Resistance DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.111 * 0.98	265.0
	Multifamily Heat Pump DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.0543 * 0.98	129.7
	Multifamily Unknown DHW	= 0.30 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.111 * 0.98	79.5
	Unknown Location	Assumes 80% SF and 20% MF[263]	69.1
Efficiency Kits – EnergyWise (Low Income)	Single Family Electric Resistance DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.111 * 0.74	167.4
	Single Family Heat Pump DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.0543 * 0.74	81.9

mode where a larger draw would kick the unit in to resistance mode (98%), or where low total water consumption can result in lower COPs due to relatively high standby losses. Note that the AHRI directory provides recovery efficiency ratings, some of which are >250% but most are rated at 100%. This is due to the rating test involving a large hot water draw, consistent with multiple showers.

260 Deemed values are from ComEd Illinois 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.

261 Based on Cadmus, "Final Report: Iowa 2015 Energy Wise Program", January 29, 2016, p16.

262 Based on results provided in "School-based interim process memo_Final_100215.doc".

263 Based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IA, see "HC2.9 Structural and Geographic in Midwest Region.xls".

Program	Market	Algorithm	ΔkWh
	Single Family Unknown DHW	= 0.30 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.111 * 0.74	50.2
	Multifamily Electric Resistance DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.111 * 0.74	200.1
	Multifamily Heat Pump DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.0543 * 0.74	97.9
	Multifamily Unknown DHW	= 0.30 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.111 * 0.74	60.0
	Unknown Location	Assumes 80% SF and 20% MF	52.2
Efficiency Kits – LivingWise (Schools)	Single Family Electric Resistance DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.111 * 0.43	97.2
	Single Family Heat Pump DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.0543 * 0.43	47.6
	Single Family Unknown DHW	= 0.30 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.111 * 0.43	29.2
	Multifamily Electric Resistance DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.111 * 0.43	116.3
	Multifamily Heat Pump DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.0543 * 0.43	56.9
	Multifamily Unknown DHW	= 0.30 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.111 * 0.43	34.9
	Unknown Location	Assumes 80% SF and 20% MF	30.3

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for showerhead use

= (GPM_base * L * Household * SPCD * 365.25 * 0.636[264])/ GPH

Program	Building Type	Calculation	Hours
Direct Install	Single Family Electric Resistance DHW (or unknown)	= (2.5 * 7.8 * 2.51 * 0.6 * 365.25 * 0.636) / 25.8	264.4
	Single Family Heat Pump DHW	= (2.5 * 7.8 * 2.51 * 0.6 * 365.25 * 0.636) / 52.7	129.4
	Multifamily Electric Resistance DHW (or unknown)	= (2.5 * 7.8 * 2.18 * 0.6 * 365.25 * 0.636) / 25.8	229.7
	Multifamily Heat Pump DHW	= (2.5 * 7.8 * 2.18 * 0.6 * 365.25 * 0.636) / 52.7	112.4
Efficiency Kits, NC and TOS	Single Family Electric Resistance DHW (or unknown)	= (2.35 * 7.8 * 2.51 * 0.6 * 365.25 * 0.636) / 25.8	248.6
	Single Family Heat Pump DHW	= (2.35 * 7.8 * 2.51 * 0.6 * 365.25 * 0.636) / 52.7	121.7
	Multifamily Electric Resistance	= (2.35 * 7.8 * 2.18 * 0.6 * 365.25 * 0.636) /	215.9

[264] 63.6% is the proportion of hot 126.5F water mixed with 56.5F supply water to give 101F shower water.

Program	Building Type	Calculation	Hours
	DHW (or unknown)	25.8	
	Multifamily Heat Pump DHW	= (2.35 * 7.8 * 2.18 * 0.6 * 365.25 * 0.636) / 52.7	105.7

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 70F temp rise (126.5-56.5), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 4.5kW electric resistance storage tank.

= 25.8 for electric resistance or unknown, 52.7 for heat pump[265]

CF = Coincidence Factor for electric load reduction

= 1.6% [266]

Based on defaults provided above:

Program	Market	Algorithm	ΔkW
Direct Install	Single Family Electric Resistance DHW	= 260.7/264.4 * 0.016	0.0158
	Single Family Heat Pump DHW	= 127.6/129.4 * 0.016	0.0158
	Single Family Unknown DHW	= 78.2/264.4* 0.016	0.0047
	Multifamily Electric Resistance DHW	= 311.8/229.7 * 0.016	0.0217
	Multifamily Heat Pump DHW	= 152.5/112.4 * 0.016	0.0217
	Multifamily Unknown DHW	= 93.5/229.7 * 0.016	0.0065
NC or TOS	Single Family Electric Resistance DHW	= 221.6/248.6 * 0.016	0.0143
	Single Family Heat Pump DHW	= 108.4/121.7 * 0.016	0.0143
	Single Family Unknown DHW	= 66.5/248.6 * 0.016	0.0043
	Multifamily Electric Resistance DHW	= 265.0/215.9 * 0.016	0.0196
	Multifamily Heat Pump DHW	= 129.7/105.7 * 0.016	0.0196
	Multifamily Unknown DHW	= 79.5/215.9 * 0.016	0.0059
	Unknown location	Assumes 80% SF and 20% MF	0.0046
Efficiency Kits – EnergyWise (Low Income)	Single Family Electric Resistance DHW	= 167.4/248.9 * 0.016	0.0108
	Single Family Heat Pump DHW	= 81.9/121.7 * 0.016	0.0108
	Single Family Unknown DHW	= 50.2/248.9 * 0.016	0.0032
	Multifamily Electric Resistance DHW	= 200.1/215.9 * 0.016	0.0148
	Multifamily Heat Pump DHW	= 97.9/105.7 * 0.016	0.0148
	Multifamily Unknown DHW	= 60.0/215.9* 0.016	0.0045
	Unknown location	Assumes 80% SF and 20% MF	0.0035
Efficiency Kits – LivingWise (Schools)	Single Family Electric Resistance DHW	= 97.2/248.9* 0.016	0.0063
	Single Family Heat Pump DHW	= 47.6/121.7 * 0.016	0.0063
	Single Family Unknown DHW	= 29.2/248.9* 0.016	0.0019
	Multifamily Electric Resistance DHW	= 116.3/215.9* 0.016	0.0086

[265] See 'Calculation of GPH Recovery_06122019.xls' for calculation details.

[266] Calculated as follows: Assume 11% showers take place during peak hours (based on: Deoreo, B., and P. Mayer. "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*65/365.25 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 216 = 4.23 hours of recovery during peak period, where 216 equals the average annual electric DHW recovery hours for showerhead use in SF 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 4.23/260 = 0.016.

Program	Market	Algorithm	ΔkW
	Multifamily Heat Pump DHW	= 56.9/105.7 * 0.016	0.0086
	Multifamily Unknown DHW	= 34.9/215.9 * 0.016	0.0026
	Unknown location	Assumes 80% SF and 20% MF	0.0020

Natural Gas Savings

$$\Delta Therms = \%FossilDHW * ((GPM\_base - GPM\_low) * L * Household * SPCD * \frac{365.25}{SPH}) * EPG\_gas * ISR$$

Where:

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

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	70%[267]

EPG_gas = Energy per gallon of hot water supplied by gas

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

= 0.00475 Therm/gal for SF or MF homes with storage tanks

= 0.00626 Therm/gal for MF homes with central boiler DHW, 0.00535 Therm/gal for MF homes with unknown DHW

Where:

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[268]

= 78% for MF homes with storage tank, 59% if hot water through central boiler or 69% if unknown[269]

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

Other variables as defined above.

Program	Market	Algorithm	ΔTherms
Direct Install	Single Family Gas DHW	= 1.0 * ((2.5 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.00475 * 0.98	11.2
	Single Family Unknown DHW	= 0.70 * ((2.5 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.00475 * 0.98	7.8
	Multifamily Gas Storage DHW	= 1.0 * ((2.5 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00475 * 0.98	13.3
	Multifamily Gas Central Boiler DHW	= 1.0 * ((2.5 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00626 * 0.98	17.6

[267] Default assumption for unknown fuel is based on Dunsky and Opinion Dynamics Baseline Study results. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.
[268] 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%.
[269] Water heating in multifamily buildings is often provided by a larger central boiler. An average efficiency of 0.69 is used for this analysis as a default for multifamily buildings where the water heating system is unknown.

Program	Market	Algorithm	ΔTherms
	Multifamily Gas Unknown DHW	= 1.0 * ((2.5 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00535 * 0.98	15.0
	Multifamily Unknown DHW	= 0.70 * ((2.5 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00535 * 0.98	10.5
NC or TOS	Single Family Gas DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.00475 * 0.98	9.5
	Single Family Unknown DHW	= 0.70 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.00475 * 0.98	6.6
	Multifamily Gas Storage DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00475 * 0.98	11.3
	Multifamily Gas Central Boiler DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00626 * 0.98	14.9
	Multifamily Gas Unknown DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00535 * 0.98	12.8
	Multifamily Unknown DHW	= 0.70 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00535 * 0.98	8.9
	Unknown location	Assumes 80% SF and 20% MF	7.1
Efficiency Kits – EnergyWise (Low Income)	Single Family Gas DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.00475 * 0.74	7.2
	Single Family Unknown DHW	= 0.70 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.00475 * 0.74	5.0
	Multifamily Gas Storage DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00475 * 0.74	8.6
	Multifamily Gas Central Boiler DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00626 * 0.74	11.3
	Multifamily Gas Unknown DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00535 * 0.74	9.6
	Multifamily Unknown DHW	= 0.70 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00535 * 0.74	6.8
	Unknown location	Assumes 80% SF and 20% MF	5.4
Efficiency Kits – LivingWise (Schools)	Single Family Gas DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.00475 * 0.43	4.2
	Single Family Unknown DHW	= 0.70 * ((2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79) * 0.00475 * 0.43	2.9
	Multifamily Gas Storage DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00475 * 0.43	5.0
	Multifamily Gas Central Boiler DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00626 * 0.43	6.6
	Multifamily Gas Unknown DHW	= 1.0 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00535 * 0.43	5.6
	Multifamily Unknown DHW	= 0.70 * ((2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3) * 0.00535 * 0.43	3.9
	Unknown location	Assumes 80% SF and 20% MF	3.1

Peak Gas Savings

Savings for this measure are assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{365.25}$$

Where:

ΔTherms = Therm impact calculated above

365.25 = Days per year

Program	Market	ΔPeakTherms
Direct Install	Single Family Gas DHW	0.0307
	Single Family Unknown DHW	0.0214
	Multifamily Gas Storage DHW	0.0364
	Multifamily Gas Central Boiler DHW	0.0482
	Multifamily Gas Unknown DHW	0.0411
	Multifamily Unknown DHW	0.0287
NC or TOS	Single Family Gas DHW	0.0260
	Single Family Unknown DHW	0.0181
	Multifamily Gas Storage DHW	0.0309
	Multifamily Gas Central Boiler DHW	0.0408
	Multifamily Gas Unknown DHW	0.0350
	Multifamily Unknown DHW	0.0244
	Unknown location	0.0194
Efficiency Kits – EnergyWise (Low Income)	Single Family Gas DHW	0.0197
	Single Family Unknown DHW	0.0137
	Multifamily Gas Storage DHW	0.0235
	Multifamily Gas Central Boiler DHW	0.0309
	Multifamily Gas Unknown DHW	0.0263
	Multifamily Unknown DHW	0.0186
	Unknown location	0.0148
Efficiency Kits – LivingWise (Schools)	Single Family Gas DHW	0.0115
	Single Family Unknown DHW	0.0079
	Multifamily Gas Storage DHW	0.0137
	Multifamily Gas Central Boiler DHW	0.0181
	Multifamily Gas Unknown DHW	0.0153
	Multifamily Unknown DHW	0.0107
	Unknown location	0.0085

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Gallons = (GPM\_base - GPM\_low) * L * Household * SPCD * \frac{365.25}{SPH} * ISR$$

Variables as defined above

Program	Market	Algorithm	ΔGallons
Direct Install	Single Family	= (2.5 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79 * 0.98	2349
	Multifamily	= (2.5 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3 * 0.98	2809
NC or TOS	Single Family	= (2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79 * 0.98	1997
	Multifamily	= (2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3 * 0.98	2388
	Unknown Location	Assumes 80% SF and 20% MF	2075
Efficiency Kits – EnergyWise (Low Income)	Single Family	= (2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79 * 0.74	1508
	Multifamily	= (2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3 * 0.74	1803
	Unknown Location	Assumes 80% SF and 20% MF	1567

Program	Market	Algorithm	ΔGallons
Efficiency Kits – LivingWise (Schools)	Single Family	= (2.35 – 1.5) * 7.8 * 2.51 * 0.6 * 365.25 / 1.79 * 0.43	876
	Multifamily	= (2.35 – 1.5) * 7.8 * 2.18 * 0.6 * 365.25 / 1.3 * 0.43	1048
	Unknown Location	Assumes 80% SF and 20% MF	910

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-V04-200101

SUNSET DATE: 1/1/2023

2.3.6 Domestic Hot Water Pipe Insulation

Description

This measure applies to the addition of insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed on the first length of both the hot and cold pipe up to the first elbow. This is the most cost effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow, which acts as a heat trap. Insulating this length therefore helps reduce standby losses.

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[270]

Deemed Measure Cost

The measure cost is the actual cost of material and installation. If the actual cost is unknown, assume a default cost of $4 per linear foot,[271] including material and installation.

Loadshape

Loadshape E01 – Flat

Loadshape G01 – Flat

Algorithm

Calculation of Savings

Electric Energy Savings

Custom calculation below for electric domestic hot water (DHW) systems, otherwise assume 24.7 kWh per 6 linear feet of ¾ in, R-4 insulation or 35.5 kWh per 6 linear feet of 1 in, R-6 insulation:

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

Where:

C_{Base} = Circumference (ft) of uninsulated pipe

= Diameter (in) * π/12 (pipe with 0.50 in diameter = 0.131 ft, pipe with 0.75 in diameter = 0.196 ft)

[270] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014. Average of values for electric DHW (13 years) and gas DHW (11 years).
[271] Consistent with DEER 2008 Measure Cost Summary, Revised June 2, 2008 (www.deeresources.com).

= Actual or if unknown, assume 0.131 ft

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

= 1.0[272]

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

= Diameter (in) * π/12

= Actual or if unknown, assume 0.524 ft for a 0.50 in diameter pipe insulated with 3/4 in, R-4 wrap ((0.5 + 3/4 + 3/4) * π/12) or 0.654 ft for a 0.50 in diameter pipe insulated with 1 in, R-6 wrap ((0.5 + 1 + 1) * π/12)[273]

R_{EE} = Thermal resistance coefficient (hr-°F-ft^2)/Btu) of insulated pipe

= 1.0 + R value of insulation

= Actual or if unknown, assume 5.0 for R-4 wrap or 7.0 for R-6 wrap

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

= Actual or if unknown, assume 6 ft

ΔT = Average temperature difference (°F) between supplied water and outside air

= Actual or if unknown, assume 60°F [274]

Hours = Hours per year

= 8,766

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

= Actual or if unknown, assume 0.98 [275]

3,412 = Conversion factor from Btu to kWh

For example, an electric DHW pipe with 6 feet of ¾ in, R-4 insulation installed, with defaults from above, would save:

$$\Delta kWh = ((C_{Base}/R_{Base} - C_{EE}/R_{EE}) * L * \Delta T * Hours) / (\eta DHW_{Elec} * 3{,}412)$$
$$= ((0.131/1.0 - 0.524/5.0) * 6 * 60 * 8{,}766) / (0.98 * 3{,}412)$$
$$= 24.7 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings from pipe wrap installation

Other variables as defined above.

272 Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77.
273 Pipe wrap thicknesses based on review of available products on Grainger.com
274 Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.
275 Electric water heaters have recovery efficiency of 98%: https://www.ahridirectory.org/Search/SearchHome

For example, an electric DHW pipe with 6 feet of ¾ in, R-4 insulation installed, with defaults from above, would save:

ΔkW = 24.7/8,766

= 0.0028 kW

NATURAL GAS SAVINGS

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

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

Where:

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

= 0.78[276]

100,000 = Conversion factor from Btu to therms

Other variables as defined above

For example, a gas DHW pipe with 6 feet of ¾ in, R-4 insulation installed, with defaults from above, would save:

ΔTherms = ((C_{Base}/R_{Base} - C_{EE}/R_{EE}) * L * ΔT * Hours) / (ηDHW_{Gas} * 100,000)

= ((0.131/1.0 – 0.524/5.0) * 6 *60 * 8,766) / (0.78 * 100,000)

= 1.1 therms

PEAK GAS SAVINGS

Savings for this measure are assumed to be evenly spread across the year.

$$\Delta PeakTherms = \Delta Therms/365.25$$

Where:

ΔTherms = Gas savings from pipe wrap insulation

365.25 = Number of days per year

For example, a gas DHW pipe with 6 feet of ¾ in, R-4 insulation installed, with defaults from above, would save:

ΔPeakTherms = 1.1/365.25

= 0.0030 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[276] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%

MEASURE CODE: RS-HWE-PINS-V01-170101

SUNSET DATE: 1/1/2023

2.3.7 Water Heater Wrap

Description

This measure applies to a tank wrap or insulation "blanket" that is wrapped around the outside of an electric or gas domestic hot water (DHW) tank to reduce stand-by losses.

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

Definition of Efficient Equipment

The efficient condition is an electric or gas DHW tank with wrap installed that has an R-value that meets program requirements.

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 7 years.[277]

Deemed Measure Cost

The measure cost is the actual cost of material and installation. If actual costs are unknown, assume $58[278] for material and installation.

Loadshape

Loadshape E01 – Flat

Loadshape G01 – Flat

Algorithm

Calculation of Savings

Electric Energy Savings

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

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

Where:

A_{Base} = Surface area (ft^2) of storage tank prior to adding tank wrap[279]

= Actual or if unknown, use default based on tank capacity (gal) from table below

R_{Base} = Thermal resistance coefficient (hr-°F-ft^2/BTU) of uninsulated tank

= Actual or if unknown, assume 14[280]

[277] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014. Average of values for electric DHW (13 years) and gas DHW (11 years).

[278] Average cost of R-10 tank wrap installation from the National Renewable Energy Laboratory's National Residential Efficiency Measures Database. http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=270

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

[280] Baseline R-value based on information from Chapter 6 of The Virginia Energy Savers Handbook, Third Edition: The best

A_{EE} = Surface area (ft^2) of storage tank after addition of tank wrap[281]

= Actual or if unknown, use default based on tank capacity (gal) from table below

R_{EE} = Thermal resistance coefficient ((hr-°F-ft2/BTU) of tank after addition of tank wrap (R-value of uninsulated tank + R-value of tank wrap)

= Actual or if unknown, assume 24

ΔT = Average temperature difference (°F) between tank water and outside air

= Actual or if unknown, assume 60°F [282]

Hours = Hours per year

= 8,766

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

= Actual or if unknown, assume 0.98 [283]

3,412 = Conversion from Btu to kWh

The following table contains default savings for various tank capacities.

Capacity (gal)	A_{Base} (ft^2)[284]	A_{EE} (ft^2)[285]	ΔkWh	ΔkW
30	19.16	20.94	78.0	0.0089
40	23.18	25.31	94.6	0.0108
50	24.99	27.06	103.4	0.0118
80	31.84	34.14	134.0	0.0153

For example, a 30 gallon electric DHW tank with an R-value of 14 before insulation is installed and an R-value of 24 after insulation is installed, with defaults from above, would save:

ΔkWh = ((A_{Base}/R_{Base} - A_{EE}/R_{EE}) * ΔT * Hours) / (ηDHW_{Elec} * 3,412)

= ((19.16/14 – 20.94/24) * 60 * 8,766) / (0.98 * 3,412)

= 78.0 kWh

Summer Coincident Peak Demand Savings

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

Where:

ΔkWh = Electric energy savings from tank wrap installation

Other variables as defined above

The table above contains default kW savings for various tank capacity and pre and post R-values.

heaters have 2 to 3 inches of urethane foam, providing R-values as high as R-20. Other less expensive models have fiberglass tank insulation with R-values ranging between R-7 and R-10.

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

282 Assumes 125°F hot water tank temperature and average temperature of basement of 65°F.

283 Electric water heaters have recovery efficiency of 98%: https://www.ahridirectory.org/Search/SearchHome

284 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.

285 Assumptions from PA TRM. A_{EE} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

For example, a 30 gallon electric DHW tank with an R-value of 14 before insulation is installed and an R-value of 24 after insulation is installed, with defaults from above, would save:

ΔkW = 78.0/8,766

= 0.0089 kW

NATURAL GAS SAVINGS

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

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

Where:

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

= 0.78[286]

100,000 = Conversion factor from Btu to therms

Other variables as defined above

The following table contains default savings for various tank capacities.

Capacity (gal)	A_{Base} (ft^2)[287]	A_{EE} (ft^2)[288]	ΔTherms	ΔPeakTherms
30	19.16	20.94	3.3	0.0092
40	23.18	25.31	4.1	0.0111
50	24.99	27.06	4.4	0.0121
80	31.84	34.14	5.7	0.0157

For example, a 30 gallon gas DHW tank with an R-value of 14 before insulation is installed and an R-value of 24 after insulation is installed, with defaults from above, would save:

ΔTherms = ((A_{Base}/R_{Base} - A_{EE}/R_{EE}) * ΔT * Hours) / (ηDHW_{Gas} * 100,000)

= ((19.16/14 – 20.94/24) * 60 * 8,766) / (0.78 * 100,000)

= 3.3 therms

PEAK GAS SAVINGS

Savings for this measure are assumed to be evenly spread across the year.

$$\Delta PeakTherms = \frac{\Delta Therms}{365.25}$$

Where:

ΔTherms = Gas savings from tanks wrap insulation

365.25 = Number of days per year

The table above contains default Peak Therm savings for various tank capacity and pre and post R-values.

[286] 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%

[287] 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.

[288] Assumptions from PA TRM. A_{EE} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

For example, a 30 gallon gas DHW tank with an R-value of 14 before installation is installed and an R-value of 24 after installation is installed, with defaults from above, would save:

$$\Delta PeakTherms = 3.3/365.25$$

$$= 0.0092 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-WRAP-V01-170101

SUNSET DATE: 1/1/2023

2.4 Heating, Ventilation, and Air Conditioning (HVAC)

2.4.1 Central 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:
   i. The installation of a new residential sized (≤ 65,000 Btu/hr) central 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:
   i. The early removal of functioning electric heating and cooling (if present) systems from service, prior to the natural end of life, and replacement with a new high efficiency central air source heat pump 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.
   ii. In order to apply Early Replacement savings, the existing unit must be functioning and SEER ≤10. "Functioning" is defined as being fully operational – providing sufficient space conditioning (i.e., heat exchanger, compressors, pumps work effectively) and/or the cost of repair is under 20% of the new baseline replacement cost. Therefore, in order to apply early replacement assumptions, the programs should apply the following eligibility criteria: SEER ≤10 and cost of any repairs <$471 per ton.

Quality Installation:

Additional savings are attributed to the Quality Installation (QI) of the system. QI programs should follow industry standards such as those described in ANSI ACCA QI5 and QI9vp. This must include considerations of system design (including sizing, matching, ventilation calculations) and equipment installation (including static pressure, airflow, refrigerant charge) and may also consider distribution.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

Time of Sale: The baseline is a new residential sized (≤ 65,000 Btu/hr) central air source heat pump meeting federal standards. The current Federal Standard efficiency level as of January 1, 2015 is 14 SEER and 8.2HSPF but for calculating savings the average of non-ENERGY STAR available product is used: 14.4 SEER, 11.8 EER and 8.2HSPF[289]. It is assumed that 'Quality Installation' did not occur.

Early replacement: The baseline 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.

[289] Based on review of available models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

Deemed Lifetime of Efficient Equipment

The expected equipment measure life is assumed to be 18 years[290]. Quality installation savings are assumed to last the time of the equipment because they come from the selection of fans and ducts, as well as airflow and other settings that do not change through normal operation of the equipment.

Remaining life of existing equipment is assumed to be 6 years[291].

Deemed Measure Cost

Time of sale: The incremental capital cost for this measure is dependent on the efficiency of the new unit[292].

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

Actual costs may be used if associated baseline costs can also be estimated for the application.

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)[293]:

Efficiency (SEER)	Full Retrofit Cost (including labor) per Ton of Capacity ($/ton)
14.5	$2,355 / ton +$123
15	$2,355 / ton +$303
16	$2,355 / ton +$438
17	$2,355 / ton +$724
18+	$2,355 / ton +$724

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $2,355 per ton of capacity[294]. This cost should be discounted to present value using the utilities' discount rate[295].

Quality Installation: The additional design and installation work associated with quality installation has been estimated to add $150 to the installed cost[296].

Loadshape

Loadshape RE08 – Residential Single Family Heat Pump

[290] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[291] Assumed to be one third of effective useful life.
[292] Based on incremental cost results from Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016.
[293] Costs based upon average cost per ton from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.
[294] Costs based upon average cost per ton from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.
[295] Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.
[296] Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers; see 'Iowa HVAC Incremental Cost Study' for details.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Cool} * \left(\frac{1}{(SEER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{(HSPF_{base} * (1 - DeratingHeat_{base}))} - \frac{1}{(HSFP_{ee} * (1 - DeratingHeat_{eff}))}\right)}{1000}\right]$$

Early replacement[297]:

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

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Cool} * \left(\frac{1}{(SEER_{exist} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{(HSPF_{exist} * (1 - DeratingHeat_{base}))} - \frac{1}{(HSFP_{ee} * (1 - DeratingHeat_{eff}))}\right)}{1000}\right]$$

ΔkWH for remaining measure life (next 12 years):

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Cool} * \left(\frac{1}{(SEER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{(HSPF_{base} * (1 - DeratingHeat_{base}))} - \frac{1}{(HSFP_{ee} * (1 - DeratingHeat_{eff}))}\right)}{1000}\right]$$

Where:

$EFLH_{cool}$ = Equivalent Full Load Hours of air conditioning

= Dependent on location[298]:

[297] 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 that would be the (new base to efficient savings)/(existing to efficient savings).

[298] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from National Climatic Data Center, NCDC).

Climate Zone (City based upon)	$EFLH_{cool}$ (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	548	918	504	736	508	865
Zone 6 (Mason City)	279	468	257	375	259	441
Average/ unknown (Des Moines)	484	811	445	650	449	764

$Capacity_{Cool}$ = Cooling capacity of Air Source Heat Pump (Btu/hr), rated at A2 conditions, 95°F outdoor dry-bulb temperature.

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

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

= 14.4[299]

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

= Actual. If unknown assume 15.1[300]

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

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

Existing Cooling System	SEER_exist[301]
Air Source Heat Pump	9.12
Central AC	8.60
No central cooling[302]	Set '1/SEER_exist' = 0

$DeratingCool_{eff}$ = Efficent ASHP Cooling derating

= 0% if Quality Installation is performed

= 10.5% if Quality Installation is not performed[303]

$DeratingCool_{base}$ = Baseline ASHP Cooling derating

= 10.5%

$EFLH_{Heat}$ = Equivalent Full Load Hours of heating

= Dependent on location[304]:

299 Based on review of available non-ES models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.
300 Based on review of available ENERGY STAR models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.
301 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren IL PY3-PY4 (2010-2012). The utilities should collect this information if possible to inform a future update.
302 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.
303 Based on Cadmus assumption in IPL TRM– results in a QI savings that is within a feasible range.
304 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Heating Degree Day ratios (from NCDC).

Climate Zone (City based upon)	$EFLH_{Heat}$ (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	1922	2022	1389	1643	1797	2137
Zone 6 (Mason City)	2732	2874	1975	2335	2554	3037
Average/ unknown (Des Moines)	2160	2272	1561	1846	2019	2401

$Capacity_{Heat}$ = Heating capacity of Air Source Heat Pump (Btu/hr) at Standard Rating Conditions (High Temperature Steady State Heating, 47°F Dry-bulb)

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

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

= 8.2[305]

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

(kBtu/kWh)

= Actual. If unknown assume 8.6[306]

$HSPF_{Exist}$ = Heating System Performance Factor (HSPF) 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 [307]
Electric Resistance or Electric Furnace	3.41 [308]

$DeratingHeat_{eff}$ = Efficent ASHP Heating derating

= 0% if Quality Installation is performed

= 11.8% if Quality Installation is not performed[309]

$DeratingHeat_{base}$ = Baseline ASHP Heating derating

= 11.8%

305 Based on review of available non-ES models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

306 Based on review of available ENERGY STAR models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

307 This is estimated based on finding the average HSPF/SEER ratio from the AHRI directory data (using the least efficient models – SEER 12 and SEER 13) – 0.596, and applying to the average nameplate SEER rating of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012). This estimation methodology appears to provide a result within 10% of actual HSPF.

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

309 Based on Cadmus assumption in IPL TRM– results in a QI savings that is within a feasible range.

Time of Sale:

For example, for a three ton, 15 SEER, 12 EER, 9 HSPF Air Source Heat Pump installed with quality installation in an existing single family home in Des Moines:

ΔkWh = ((811 * 36,000 * (1/(14.4 * (1-10.5%)) - 1/(15 * (1-0%)))) / 1000) + ((2272 * 36,000 * (1/(8.2 * (1-11.8%)) - 1/(9 * (1-0%)))) / 1000)

= 2540.0 kWh

For example, for a three ton, 15 SEER, 12 EER, 9 HSPF Air Source Heat Pump installed without quality installation in an existing single family home in Des Moines:

ΔkWh = ((811 * 36,000 * (1/(14.4 * (1-10.5%)) - 1/(15 * (1-10.5%)))) / 1000) + ((2272 * 36,000 * (1/(8.2 * (1-11.8%)) - 1/(9 * (1-11.8%)))) / 1000)

= 1095.9 kWh

Early Replacement:

For example, for a three ton, 15 SEER, 12 EER, 9 HSPF Air Source Heat Pump that replaces an existing working Air Source Heat Pump using quality installation with unknown efficiency ratings in Des Moines:

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

= ((811 * 36,000 * (1/(9.12 * (1-10.5%)) - 1/(15 * (1-0%)))) / 1000) + ((2272 * 36,000 * (1/(5.44 * (1-11.8%)) - 1/(9 * (1-0%)))) / 1000)

= 9589.3 kWh

ΔkWH for remaining measure life (next 12 years):

= ((811 * 36,000 * (1/(14.4 * (1-10.5%)) - 1/(15 * (1-0%)))) / 1000) + ((2272 * 36,000 * (1/(8.2 * (1-11.8%)) - 1/(9 * (1-0%)))) / 1000)

= 2540.0 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000} * CF\right]$$

Early replacement[310]:

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

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER_{exist} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000} * CF\right]$$

ΔkW for remaining measure life (next 12 years):

[310] 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 that would be the (new base to efficient savings)/(existing to efficient savings).

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000} * CF\right]$$

Where:

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

= 11.8 [311]

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

= Actual - If not provided, convert SEER to EER using this formula:[312]

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

Or if unknown assume 12.5[313]

EER_{exist} = Energy Efficiency Ratio (EER) 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:

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

If SEER rating unavailable, use:

Existing Cooling System	EER_exist[314]
Air Source Heat Pump	8.55
Central AC	8.15
No central cooling[315]	Set '1/EER_exist' = 0

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

= 0% if Quality Installation is performed and/or if unit is right-sized

= 10.5% if Quality Installation is not performed[316]

$DeratingCool_{base}$ = Baseline Central Air Conditioner Cooling derating

= 10.5%

CF = Summer system peak Coincidence Factor for cooling

= 72%[317] for non-QI

311 Based on review of available non-ES models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

312 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.

313 Based on review of available ENERGY STAR models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

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

315 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.

316 Based on Cadmus assumption in IPL TRM– results in a QI savings that is within a feasible range.

317 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

= 80%[318] for QI or right sized units

Time of Sale:

For example, for a three ton, 15 SEER, 12.5 EER, 9 HSPF Air Source Heat Pump installed <u>with</u> quality installation in Des Moines:

ΔkW = ((36,000 * (1/(11.8 * (1 – 10.5%)) – 1/(12.5 * (1 – 0%)))) / 1000) * 80%

= 0.4230 kW

For example, for a three ton, 15 SEER, 12.5 EER, 9 HSPF Air Source Heat Pump installed <u>without</u> quality installation in Des Moines:

ΔkW = ((36,000 * (1/(11.8 * (1 – 10.5%)) – 1/(12.5 * (1 – 10.5%)))) / 1000) * 72%

= 0.1374kW

Early Replacement:

For example, for a three ton, 15 SEER, 12.5 EER, 9 HSPF Air Source Heat Pump that replaces an existing working Air Source Heat Pump with quality installation and with unknown efficiency ratings in Des Moines:

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

= ((36,000 * (1/(8.55 * (1 – 10.5%)) - 1/(12.5 * (1 – 0%)))) / 1000) * 80%

= 1.4596 kW

ΔkW for remaining measure life (next 12 years):

= ((36,000 * (1/(11.8 * (1 – 10.5%)) – 1/(12.5 * (1 – 0%)))) / 1000) * 80%

= 0.4230 kW

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ASHP-V04-200101

SUNSET DATE: 1/1/2022

[318] This higher CF accounts for the demand benefit from right sizing the equipment,

2.4.2 Central Air Conditioner

Description

This measure characterizes:

a) Time of Sale:
   i. The installation of a new high efficiency residential Central Air Conditioner ducted split system. 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. The characterization can be used for both residential sized units (< 65,000 Btu/hr) and larger units (≥65,000 and <135,000 Btu/hr).

b) Early Replacement:
   i. The early removal of an existing inefficient Central Air Conditioner unit from service, prior to its natural end of life, and replacement with a new 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.
   ii. In order to apply Early Replacement savings, the existing unit must be functioning and SEER ≤10. "Functioning" is defined as being fully operational – providing sufficient space conditioning (i.e., heat exchanger, compressors, pumps work effectively) and/or the cost of repair is under 20% of the new baseline replacement cost. Therefore, in order to apply early replacement assumptions, the programs should apply the following eligibility criteria: SEER ≤10 and cost of any repairs <$437 per ton.

Quality Installation:

Additional savings are attributed to the Quality Installation (QI) of the system. QI programs should follow industry standards such as those described in ANSI ACCA QI5 and QI9vp. This must include considerations of system design (including sizing, matching, ventilation calculations) and equipment installation (including static pressure, airflow, refrigerant charge) and may also consider distribution.

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a ducted split Central Air Conditioner unit meeting or exceeding the minimum efficiency standards set by the utility and at least ≥14 SEER and 11.5 EER (note the v5 ENERGY STAR efficiency level standards: 15 SEER and 12.5 EER[319]).

Definition of Baseline Equipment

The current Federal Standard efficiency level is 13 SEER and 11.2 EER[320] for units <65,000 Btu/hr or 11.4 IEER and 11.2 EER for units ≥65,000 Btu/hr[321]. For calculating savings for units <65,000 Btu/hr, the average of non-ENERGY STAR available product is used: 13.6 SEER and 11.5 EER. It is assumed that 'Quality Installation' did not occur.

The baseline for the early replacement measure is the efficiency of the existing equipment for the assumed

[319] Version 5.0 ENERGY STAR specifications, effective September 15, 2015.

[320] 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: $(-0.02 * SEER^2) + (1.12 * SEER)$ (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).

[321] Based on IECC 2012 requirements.

remaining useful life of the unit and the new baseline as defined above[322] for the remainder of the measure life.

Deemed Lifetime of Efficient Equipment

The expected equipment measure life is assumed to be 18 years [323]. Quality installation savings are assumed to last the lifetime of the equipment because they come from the selection of fans and ducts, as well as airflow and other settings that do not change through normal operation of the equipment.

Remaining life of existing equipment is assumed to be 6 years[324].

Deemed Measure Cost [325]

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed costs are provided below[326]:

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

Actual costs may be used if associated baseline costs can also be estimated for the application.

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)[327]:

Efficiency Level (SEER)	Full Retrofit Cost per Ton of Capacity ($/ton)
14	$2,185/ ton + $0
15	$2,185/ ton + $108
16	$2,185/ ton + $221
17	$2,185/ ton + $620
18+	$2,185/ ton + $620

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $2,185[328]. This cost should be discounted to present value using the utilities' discount rate[329].

Quality Installation: The additional design and installation work associated with quality installation has been estimated to add $150 to the installed cost[330].

322 Baseline SEER and EER should be updated when new minimum federal standards become effective.
323 Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. The "lifespan" of a central air conditioner is about 15 to 20 years. See reference file "GDS_MeasureLifeStudy_1Jun2007.".
324 Assumed to be one third of effective useful life.
325 Measure costs will be updated when results of MidAmerican's HVAC incremental cost study are available.
326 Based on incremental cost results from Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016.
327 Costs based upon average cost per ton from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.
328 Costs based upon average cost per ton from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.
329 Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.
330 Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE02 – Residential Multifamily Cooling

Algorithm

Calculation of Savings

Electric Energy Savings

Time of sale:

For units with cooling capacities less than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Coolee} * \left(\frac{1}{(SEER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right]$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Coolee} * \left(\frac{1}{(IEER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(IEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right]$$

Early replacement[331]:

For units with cooling capacities less than 65 kBtu/hr:

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

$$\Delta kWh = \left[\frac{EFLH_{cool} * \left(Capacity_{Coolexist} * \frac{1}{(SEER_{exist} * (1 - DeratingCool_{base}))}\right) - \left(Capacity_{Coolee} * \frac{1}{(SEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right]$$

ΔkWH for remaining measure life (next 12 years):

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Coolee} * \left(\frac{1}{(SEER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right]$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

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

[331] 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 that would be the (new base to efficient savings)/(existing to efficient savings).

$$\Delta kWh = \left[\frac{EFLH_{cool} * \left(Capacity_{Coolexist} * \frac{1}{(IEER_{exist} * (1 - DeratingCool_{base}))}\right) - \left(Capacity_{Coolee} * \frac{1}{(IEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right]$$

ΔkWH for remaining measure life (next 12 years):

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Coolee} * \left(\frac{1}{(IEER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(IEER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right]$$

Where:

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

= Dependent on location[332]:

Climate Zone (City based upon)	$EFLH_{cool}$ (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	548	918	504	736	508	865
Zone 6 (Mason City)	279	468	257	375	259	441
Average/ unknown (Des Moines)	484	811	445	650	449	764

$Capacity_{Coolee}$ = Cooling capacity of new equipment in Btu/hr (note 1 ton = 12,000Btu/hr)

= Actual installed - If actual size unknown, assume 36,000

$Capacity_{Coolexist}$ = Cooling capacity of existing equipment in Btu/hr (note 1 ton = 12,000Btu/hr)

= Actual - If actual size unknown, assume same as new installed unit

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

= 13.6[333]

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

= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown, assume:

Existing Cooling System	SEER_exist[334]
Air Source Heat Pump	9.12
Central AC	8.60

SEERee = Seasonal Energy Efficiency Ratio (SEER) of efficient unit (kBtu/kWh)

[332] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

[333] Based on review of available non-ES models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

[334] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren IL PY3-PY4 (2010-2012). The utilities should collect this information if possible to inform a future update.

= Actual installed or 15 if ENERGY STAR[335]

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

= 0% if Quality Installation is performed

= 10.5% if Quality Installation is not performed[336]

$DeratingCool_{base}$ = Baseline Central Air Conditioner Cooling derating

= 10.5%

IEERbase = Integrated Energy Efficiency Ratio (IEER) of baseline unit (kBtu/kWh)

= 11.4[337]

IEERexist = Integrated Energy Efficiency Ratio (IEER) of existing unit (kBtu/kWh)

= Use actual IEER rating where it is possible to measure, or reasonably estimate

IEERee = Integrated Energy Efficiency Ratio (IEER) of efficient unit (kBtu/kWh)

= Actual installed

Time of Sale:

For example, for a 3 ton unit with SEER rating of 15, in unknown location with quality installation:

ΔkWH = (811 * 36,000 * (1/(13.6 * (1-10.5%)) – 1/(15 * (1-0%)))) / 1000

= 452.2 kWh

For example, for a 3 ton unit with SEER rating of 15, in unknown location without quality installation:

ΔkWH = (811 * 36,000 * (1/(13.6 * (1-10.5%)) – 1/(15 * (1-10.5%)))) / 1000

= 223.9 kWh

Early Replacement:

For example, for a 3 ton unit, with SEER rating of 15 replacing an existing unit with quality installation with unknown efficiency in a single family home in Burlington, IA:

ΔkWH(for first 6 years) = (918 * 36,000 * (1/(10* (1-10.5%)) – 1/(15 * (1-0%)) / 1000

= 1,489.3 kWh

ΔkWH(for next 12 years) = (918 * 36,000 * (1/(13.6 * (1-10.5%)) – 1/(15 * (1-0%)))) / 1000

= 511.9 kWh

Therefore, record a savings adjustment of 34% (511.9/1489.3) after 6 years.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

335 Based on review of available ENERGY STAR models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

336 Based on Cadmus assumption in IPL TRM– results in a QI savings that is within a feasible range.

337 Based on IECC 2012 requirements.

$$\Delta kW = \left[\frac{Capacity_{Coolee} * \left(\frac{1}{(EER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right] * CF$$

Early replacement[338]:

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

$$\Delta kW = \left[\frac{\left(Capacity_{Coolexist} * \frac{1}{(EER_{exist} * (1 - DeratingCool_{base}))}\right) - \left(Capacity_{Coolee} * \frac{1}{(EER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right] * CF$$

ΔkW for remaining measure life (next 12 years):

$$\Delta kW = \left[\frac{Capacity_{Coolee} * \left(\frac{1}{(EER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{ee} * (1 - DeratingCool_{eff}))}\right)}{1000}\right] * CF$$

Where:

EER_{base} = Energy Efficiency Ratio (EER) of baseline unit

= 11.5 [339]

EER_{exist} = Energy Efficiency Ratio (EER) of existing unit

= Actual EER of unit should be used - If EER is unknown, use 9.2[340]

EER_{ee} = Energy Efficiency Ratio (EER) of efficient unit

= Actual installed - Or 12.5 if ENERGY STAR[341]

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

= 0% if Quality Installation is performed and/or if unit is right-sized

= 10.5% if Quality Installation is not performed[342]

$DeratingCool_{base}$ = Baseline Central Air Conditioner Cooling derating

= 10.5%

CF = Summer system peak Coincidence Factor for cooling

---

338 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 that would be the (new base to efficient savings)/(existing to efficient savings).

339 Based on review of available non-ES models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

340 Based on SEER of 10,0, using formula above to give 9.2 EER.

341 Based on review of available ENERGY STAR models on AHRI directory on 04/19/2017. See 'CAC and ASHP AHRI average_04262017.xls'.

342 Based on Cadmus assumption in IPL TRM– results in a QI savings that is within a feasible range.

= 68%[343] for non-QI

= 80%[344] for QI or right sized units

Time of Sale:

For example, for a 3 ton unit with EER rating of 12.5 installed <u>with</u> quality installation/right sized in unknown location:

ΔkW = (36,000 * (1/(11.5 * (1 – 10.5%)) – 1/(12.5 * (1 – 0%)))) / 1000 * 0.80

= 0.4942 kW

For example, for a 3 ton unit with EER rating of 12.5 installed <u>without</u> quality installation in unknown location:

ΔkW = (36,000 * (1/(11.5 * (1 – 10.5%)) – 1/(12.5 * (1 – 10.5%)))) / 1000 * 0.68

= 0.1903 kW

Early Replacement:

For example, for a 3 ton unit, with EER rating of 12 replacing an existing unit with unknown efficiency in a single family home in Burlington, IA with quality installation:

ΔkW (for first 6 years) = (36,000 * (1/(9.2 * (1 – 10.5%)) – 1/(12.5 * (1 – 0%)))) / 1000 * 0.80

= 1.1937 kW

ΔkW (for next 12 years) = (36,000 * (1/(11.5 * (1 – 10.5%)) – 1/(12.5 * (1 – 0%)))) / 1000 * 0.80

= 0.4942 kW

Natural Gas Savings

N/A

Peak Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-HVC-CAC-V04-200101

Sunset Date: 1/1/2022

343 Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'. This would account for variance in usage pattern across a population as well as oversizing of equipment.

344 This higher CF accounts for the demand benefit from right sizing the equipment,

2.4.3 Boiler

Description

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

This measure characterizes:

a) Time of Sale:
   i. The installation of a residential sized (<300,000 Btuh/h) 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:
   i. The early removal of an existing functional boiler from service, prior to its natural end of life, and replacement with a residential sized (<300,000 Btuh/h) 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.
   ii. In order to apply Early Replacement savings, the existing unit must be functioning and AFUE ≤75%. “Functioning” is defined as being fully operational – providing sufficient space conditioning (i.e. heat exchanger, compressors, pumps work effectively) and/or the cost of repair is under 20% of the new baseline replacement cost. Therefore in order to apply early replacement assumptions the programs should apply the following eligibility criteria: AFUE ≤75% and cost of any repairs <$767.

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 a residential sized (<300,000 Btuh/h) unit that meets or exceeds the efficiency requirements determined by the program.

Definition of Baseline Equipment

Time of sale: The baseline equipment for this measure is a new residential sized (<300,000 Btuh/h), gas-fired, standard-efficiency water boiler. The current Federal Standard minimum AFUE rating is 82%.

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[345].

Early replacement: Remaining life of existing equipment is assumed to be 8 years[346].

Deemed Measure Cost

Time of sale: The incremental install cost for this measure is provided below, dependent on efficiency[347]:

[345] Federal Appliance Standards, Chapter 8.3 of DOE Technical Support Documents, Table 8.3.3.

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

[347] Based on data provided in Federal Appliance Standards, Chapter 8.3, of DOE Technical Support Documents; Table 8.5.6 LCC

AFUE	Full Install Cost	Incremental Install Cost
82%	$3,835	N/A
85%	$4,468	$633
86%	$5,264	$1,429
87%	$5,276*	$1,441
88%	$5,397*	$1,562
89%	$5,518*	$1,683
90%	$5,638*	$1,803
91%	$5,583	$1,748
92%	$5,734*	$1,899
93%	$5,885*	$2,050
94%	$6,036*	$2,201
95%	$6,188*	$2,353
96%	$6,339*	$2,504
97%	$6,490*	$2,655
98%	$6,641*	$2,806
99%	$6,792	$2,957

Actual costs may be used if associated baseline costs can also be estimated for the application.

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 $3,835. This cost should be discounted to present value using the utilities' discount rate[348].

LOADSHAPE

Loadshape RG01 – Residential Boiler

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Time of Sale:

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{(AFUE_{eff} * (1 - Derating_{Eff}))}{(AFUE_{base} * (1 - Derating_{Base}))} - 1\right)}{100{,}000}$$

and PBP Results for Hot-Water Gas Boilers (High Cost). Where efficiency ratings are not provided, the values are interpolated from those that are and market with an *. See "Boiler_DOE Chapter 8.xls" for more information.

[348] Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.

Early replacement[349]:

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

$$= \frac{EFLH * Capacity * \left(\frac{(AFUE_{eff} * (1 - Derating_{Eff}))}{(AFUE_{exist} * (1 - Derating_{Base}))} - 1\right)}{100{,}000}$$

ΔTherms for remaining measure life (next 17 years):

$$= \frac{EFLH * Capacity * \left(\frac{(AFUE_{eff} * (1 - Derating_{Eff}))}{(AFUE_{base} * (1 - Derating_{Base}))} - 1\right)}{100{,}000}$$

Where:

EFLH = Equivalent Full Load Hours for heating

= Dependent on location[350]:

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	766	883	534	750	651	904
Zone 6 (Mason City)	1090	1253	759	1065	926	1284
Average/ unknown (Des Moines)	861	991	601	842	732	1015

Capacity = Nominal heating input capacity boiler size (Btu/hr) for efficient unit not existing unit

= Actual

$AFUE_{exist}$ = Existing boiler Annual Fuel Utilization Efficiency (AFUE) rating

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

If unknown, assume 61.6 AFUE%[351]

$AFUE_{base}$ = Baseline boiler Annual Fuel Utilization Efficiency (AFUE) rating

= 82%

$AFUE_{eff}$ = Efficent boiler Annual Fuel Utilization Efficiency (AFUE) rating

[349] 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 that would be the (new base to efficient savings)/(existing to efficient savings).

[350] Full load hours for Des Moines are based on analysis performed by Tetra Tech in April, 2018. Tetra Tech gathered MidAmerican program data from two residential programs with installs between October 2012 to December 2016, and matched them with gas meter consumption data following the install. Regression models were performed to estimate the Normalized Annual Heating (NAH) consumption. EFLH is then estimated by dividing NAH by the units capacity. See "Res Furnace EFLH Findings_30April2018.ppt" for more information. The resulting value of 991 hours for a single family existing home in Des Moines is scaled to other building types using the relative assumptions based upon the Cadmus modeling exercise performed for the 2011 Joint Assessment, and to other climate zones based on relative Heating Degree Day ratios (from NCDC).

[351] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012). The utilities should collect this information if possible to inform a future update.

= Actual

$Derating_{Eff}$ = Derating of AFUE to account for units not operating in field at rated efficiency

= 5.9%[352]

$Derating_{Base}$ = Derating of AFUE to account for units not operating in field at rated efficiency

= 3.3%[353]

Time of Sale:

For example, for a 100,000 Btuh 92% AFUE boiler purchased and installed for existing home in Des Moines:

ΔTherms = (991 * 100000 * ((0.92 * (1-0.059))/(0.82 * (1-0.033)) – 1))/100000

= 91.0 Therms

Early Replacement:

For example, for an existing functioning boiler with unknown efficiency that is replaced with a 100,000 Btuh, 88% AFUE boiler purchased and installed in Des Moines:

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

= (991 * 100000 * ((0.88 * (1-0.059))/(0.616 * (1-0.033)) – 1))/100000

= 386.6 Therms

ΔTherms for remaining measure life (next 17 years):

= (991 * 100000 * ((0.88 * (1-0.059))/(0.82 * (1-0.033)) – 1))/100000

= 43.9 Therms

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for heating[354]

= 0.014378 for Residential Boiler

Time of Sale:

For example, for a 100,000 Btuh 88% AFUE boiler purchased and installed for existing home in Des Moines:

ΔTherms = 43.9 * 0.014378

= 0.6312 Therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

[352] Based on findings from Massachusetts study; Cadmus “High Efficiency Heating Equipment Impact Evaluation”, March 2015.
[353] Ibid.
[354] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

MEASURE CODE: RS-HVC-GHEB-V03-190101

SUNSET DATE: 1/1/2022

2.4.4 Furnace

Description

This measure covers the installation of a residential sized (<225,000 Btuh/h) high efficiency gas furnace in a residential application. High efficiency gas furnaces achieve savings through the use of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gases. Because multiple heat exchangers are used to remove waste heat from the escaping flue gases, most of the flue gases condense and must be drained. Furnaces equipped with ECM fan motors can save additional electric energy. The ECM furnace fan is a separate measure.

This measure characterizes:

a) Time of Sale:
   i. The installation of a new residential sized (<225,000 Btuh/h) high efficiency, gas-fired 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:
   i. The early removal of an existing functional furnace from service, prior to its natural end of life, and replacement with a new residential sized (<225,000 Btuh/h) 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.
   ii. In order to apply Early Replacement savings, the existing unit must be functioning and AFUE ≤75%. “Functioning” is defined as being fully operational – providing sufficient space conditioning (i.e. heat exchanger, compressors, pumps work effectively) and/or the cost of repair is under 20% of the new baseline replacement cost. Therefore, in order to apply early replacement assumptions the programs should apply the following eligibility criteria: AFUE ≤75% and cost of any repairs <$516.

Quality Installation:

Additional savings are attributed to the Quality Installation (QI) of the system. QI programs should follow industry standards such as those described in ANSI ACCA QI5 and QI9vp. This must include considerations of system design (including sizing, matching, ventilation calculations) and equipment installation (including static pressure, airflow, combustion efficiency) and may also consider distribution.

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

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a furnace with input energy < 225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating that meets program standards.

Definition of Baseline Equipment

Time of Sale or New Construction: The baseline for this measure is an AFUE rating of 85%[355]. It is assumed that ‘Quality Installation’ did not occur.

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[355] The Federal Standard of 80% is inflated to 85% for Furnaces to account for significant market demand above the Federal minimum. This is based upon agreement of the Technical Advisory Committee, reviewing information from other jurisdictions and in lieu of Iowa-specific information. Note that when an IA net-to-gross (NTG) factor is determined for this measure, this adjusted baseline should be replaced with the appropriate Federal Standard efficiency level.

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.

DEFINITION OF MEASURE LIFE

The expected equipment measure life is assumed to be 20 years[356]. Quality installation savings are assumed to last the time of the equipment because they come from the selection of fans and ducts, as well as airflow and other settings that do not change through normal operation of the equipment.

For early replacement: Remaining life of existing equipment is assumed to be 6 years[357].

DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below[358]:

AFUE	Full Install Cost	Incremental Install Cost
85%	$4,030	N/A
86%	$4,086	$56
87%	$4,143	$113
88%	$4,199	$169
89%	$4,256	$226
90%	$4,312	$282
91%	$4,369	$339
92%	$4,425	$395
93%	$4,482	$452
94%	$4,538	$508
95%	$4,595	$565
96%	$4,888	$858
97%	$5,181	$1,151
98%	$5,474	$1,444
99%	$5,768	$1,738

Actual costs may be used if associated baseline costs can also be estimated for the application.

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 6 years) of replacing existing equipment with a new baseline unit is assumed to be $4,312[359]. This cost should be discounted to present value using the utilities' discount rate[360].

Quality Installation: The additional design and installation work associated with quality installation has been estimated to add $90 to the installed cost[361].

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356 Federal Appliance Standards, Chapter 8.3 of DOE Technical Support Documents, Table 8.3.3.

357 Assumed to be one third of effective useful life

358 Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers. Full install costs are interpolated from data provided in the 2018 MA 'Water Heating, boiler and Furnace Cost Study' and adjusted from MA to IA costs using the 2016 implicit regional price deflators from the Bureau of Economic Analysis. See "Iowa Incremental Cost Study2_Adjusted.xls" for more information.

359 This assumes that by the time the existing unit would need to be replaced (in 6 years), the new Federal Standard will be in place that makes the baseline 90% (as was rescinded in 2012).

360 Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.

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

Loadshape

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Savings

Electric Energy Savings

N/A. See Furnace Blower Motor

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

Time of Sale:

$$\Delta Therms = \frac{\frac{EFLH * Capacity}{(1 - Derating_{eff})} * \left(\frac{AFUE_{eff} * (1 - Derating_{eff})}{AFUE_{base} * (1 - Derating_{base})} - 1\right)}{100{,}000}$$

Early replacement[362]:

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

$$= \frac{\frac{EFLH * Capacity}{(1 - Derating_{eff})} * \left(\frac{AFUE_{eff} * (1 - Derating_{eff})}{AFUE_{exist} * (1 - Derating_{base})} - 1\right)}{100{,}000}$$

ΔTherms for remaining measure life (next 14 years):

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

Where:

EFLH = Equivalent Full Load Hours for heating

= Dependent on location[363]:

[362] 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 that would be the (new base to efficient savings)/(existing to efficient savings).

[363] Full load hours for Des Moines are based on analysis performed by Tetra Tech in April, 2018. Tetra Tech gathered MidAmerican program data from two residential programs with installs between October 2012 to December 2016, and matched them with gas meter consumption data following the install. Regression models were performed to estimate the Normalized Annual Heating (NAH) consumption. EFLH is then estimated by dividing NAH by the units capacity. See "Res Furnace EFLH Findings_30April2018.ppt" for more information. The resulting value of 991 hours for a single family existing home in Des Moines is scaled to other building types using the relative assumptions based upon the Cadmus modeling exercise performed for the 2011 Joint Assessment, and to other climate zones based on relative Heating Degree Day ratios (from NCDC).

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	766	883	534	750	651	904
Zone 6 (Mason City)	1090	1253	759	1065	926	1284
Average/ unknown (Des Moines)	861	991	601	842	732	1015

Capacity = Nominal heating input capacity furnace size (Btu/hr) for efficient unit not existing unit

= Actual

$AFUE_{exist}$ = Existing furnace Annual Fuel Utilization Efficiency (AFUE) rating

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

If unknown, assume 64.4 AFUE%[364]

$AFUE_{base}$ = Baseline furnace Annual Fuel Utilization Efficiency (AFUE) rating

= 85%

Note that when an IA net-to-gross (NTG) factor is determined for this measure, this adjusted baseline should be replaced with the appropriate Federal Standard efficiency level.

$AFUE_{eff}$ = Efficent furnace Annual Fuel Utilization Efficiency (AFUE) rating

= Actual

$Derating_{eff}$ = Efficent furnace AFUE derating

= 0% if Quality Installation is performed

= 6.4% if Quality Installation is not performed[365]

$Derating_{base}$ = Baseline furnace AFUE derating

= 6.4%[366]

[364] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012). The utilities should collect this information if possible to inform a future update.

[365] 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.

[366] As above

Time of Sale:

For example, for an 80,000 Btuh 95% AFUE furnace purchased and installed with quality installation for an existing home in Des Moines:

ΔTherms = ((991 * 80000)/(1 - 0%) * (((0.95 * (1 – 0%)) / (0.85 * (1 – 6.4%))) – 1)/100000

= 153.9 Therms

For example, for an 80,000 Btuh 95% AFUE furnace purchased and installed without quality installation for an existing home in Des Moines:

ΔTherms = ((991 * 80000)/(1 – 6.4%) * (((0.95 * (1 – 6.4%)) / (0.85 * (1 – 6.4%))) – 1)/100000

= 99.6 Therms

Early Replacement:

For example, for an existing functioning furnace with unknown efficiency that is replaced with an 80,000 Btuh, 95% AFUE furnace using quality installation in Des Moines:

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

= ((991 * 80000)/(1 - 0%) * (((0.95 * (1 – 0%)) / (0.644 * (1 – 6.4%))) – 1)/100000

= 456.7 Therms

ΔTherms for remaining measure life (next 14 years):

= ((991 * 80000)/(1 - 0%) * (((0.95 * (1 – 0%)) / (0.85 * (1 – 6.4%))) – 1)/100000

= 153.9 Therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for heating[367]

= 0.016525 for Residential Space Heating (other)

Time of Sale:

For example, for an 80,000 Btuh 95% AFUE furnace purchased and quality installed in an existing home in Des Moines:

ΔTherms = 153.9 * 0.016525

= 2.54 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[367] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

MEASURE CODE: RS-HVC-FRNC-V03-190101

SUNSET DATE: 1/1/2020

2.4.5 Furnace Blower Motor

NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2019. IT SHOULD NOT BE USED BEYOND THAT DATE BUT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES.

DESCRIPTION

A new furnace with a brushless permanent magnet furnace blower motor (BPM) (also known as an Electronically Commutated Motor (ECM)) 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 design, and clean, low pressure drop filters can maximize savings. Savings improve when the blower is used for cooling as well as when it is used for continuous ventilation, but only if the non-BPM motor would have been used for continuous ventilation as well. If the resident runs the BPM blower continuously because it is a more efficient motor and would not run a non-BPM motor in the same 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 also includes a section accounting for the interactive effect of reduced waste heat on the heating loads.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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[368].

DEEMED MEASURE COST

The capital cost for this measure is assumed to be $97[369] if a stand-alone measure or $0 if coupled with 2.4.4 Furnace measure, since incremental cost of a fan will be included in that measure cost.

LOADSHAPE

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

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[368] Consistent with assumed life of a new gas furnace. Federal Appliance Standards, Chapter 8.3 of DOE Technical Support Documents, Table 8.3.3.

[369] Adapted from Tables 8.2.3 and 8.2.13 in Technical Support Documents for Federal residential appliance standards: "Chapter 8, Life-Cycle Cost and Payback Period Analysis", 2011. This is for new furnaces, not retrofitting an existing furnace.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Heating\ Savings + Cooling\ Savings + Shoulder\ Season\ Savings$$

Where:

Heating Savings = Blower motor savings during heating season[370]

			Heating Savings (kWh)		
Building Type	Vintage	End Use	Des Moines	Burlington	Mason City
Manufactured	Existing	Heat Central Furnace	301.6	268.4	381.5
Manufactured	New	Heat Central Furnace	217.4	193.5	275.0
Multifamily	Existing	Heat Central Furnace	250.1	222.6	316.4
Multifamily	New	Heat Central Furnace	178.5	158.8	225.7
Single-family	Existing	Heat Central Furnace	294.4	262.0	372.4
Single-family	New	Heat Central Furnace	255.9	227.7	323.7
Residential[371]	Residential	Heat Central Furnace	290.0		

Cooling Savings = Blower motor savings during cooling season

If home has Central AC:

			Cooling Savings with CAC (kWh)		
Building Type	Vintage	End Use	Des Moines	Burlington	Mason City
Manufactured	Existing	Cool Central	252.3	266.2	208.0
Manufactured	New	Cool Central	209.2	217.3	183.1
Multifamily	Existing	Cool Central	236.7	248.5	199.0
Multifamily	New	Cool Central	208.6	216.7	182.8
Single-family	Existing	Cool Central	258.8	273.5	211.7
Single-family	New	Cool Central	214.0	222.7	185.9
Residential	Residential	Cool Central	256.5		

If No Central AC = 147.6 kWh[372]

If unknown[373]:

			Cooling Savings, if cooling unknown (kWh)		
Building Type	Vintage	End Use	Des Moines	Burlington	Mason City
Manufactured	Existing	Cool Central	237.6	249.4	199.5

[370] To estimate heating, cooling, and shoulder season savings for Iowa, 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 equivalent full load hour assumptions for Iowa. See: FOE to IA Blower Savings.xlsx.
[371] Where location and home type is unknown.
[372] These savings are for those homes that use the fan on continuous mode (13% of households) from Focus on Energy study.
[373] The weighted average value is based on assumption that 86% of homes installing BPM furnace blower motors have Central AC. Using the formula from Note 1 in Table B-2 in the FOE study, and assuming that before the furnace purchase, purchasing households have the statewide average CAC penetration, and that the percent of purchasers that add CAC during the purchase is the same in IA as WI.

			Cooling Savings, if cooling unknown (kWh)		
Building Type	**Vintage**	**End Use**	**Des Moines**	**Burlington**	**Mason City**
Manufactured	New	Cool Central	200.5	207.4	178.1
Multifamily	Existing	Cool Central	224.1	234.2	191.7
Multifamily	New	Cool Central	200.0	206.9	177.8
Single-family	Existing	Cool Central	243.1	255.7	202.7
Single-family	New	Cool Central	204.6	212.1	180.5
Residential	Residential	Cool Central	241.1		

Shoulder Season Savings = Blower motor savings during shoulder seasons

= 24.3 kWh

Using default values above the total savings are provided below:

		Total Savings (kWh)								
		With CAC			No CAC			Unknown CAC		
Building Type	**Vintage**	**Des Moines**	**Burlington**	**Mason City**	**Des Moines**	**Burlington**	**Mason City**	**Des Moines**	**Burlington**	**Mason City**
Manufactured	Existing	578.2	558.9	613.8	473.5	440.3	553.4	563.5	542.1	605.3
Manufactured	New	450.9	435.1	482.5	389.3	365.4	447.0	442.2	425.3	477.4
Multifamily	Existing	511.1	495.4	539.7	422.0	394.5	488.3	498.6	481.2	532.5
Multifamily	New	411.4	399.8	432.9	350.4	330.7	397.7	402.8	390.0	427.9
Single-family	Existing	577.5	559.8	608.4	466.3	433.9	544.3	561.8	542.0	599.4
Single-family	New	494.2	474.8	533.9	427.8	399.6	495.6	484.8	464.2	528.5
Residential	Residential	570.8			462.0			555.5		

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\frac{NoACCooling\ Savings}{Cooling\ Season\ Hours} + \frac{Cooling\ Savings - NoACCooling\ Savings}{FLH\_cooling}\right) * CF$$

Where:

NoACCooling Savings = kWh savings in cooling season for homes without cooling

= 147.6 kWh

Cooling Season Hours = Total hours during cooling season

= 2952[374]

Cooling Savings = kWh savings in cooling season for homes with cooling

= See tables above

FLH_cooling = Full load hours of air conditioning

= Dependent on location[375]:

		Cooling Load Hours—EFLHc		
Building Type	**Vintage**	**Des Moines**	**Burlington**	**Mason City**
Manufactured	Existing	764	865	441
Manufactured	New	449	508	259

[374] Based on 123 days where CDD 65>0, multiplied by 24.

[375] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

		Cooling Load Hours—EFLHc		
Building Type	Vintage	Des Moines	Burlington	Mason City
Multifamily	Existing	650	736	375
Multifamily	New	445	504	257
Single-family	Existing	811	918	468
Single-family	New	484	548	279
Residential	Residential	794		

CF = Summer System Peak Coincidence Factor for Cooling

= 68%[376]

Using default values above the total savings are provided below:

		Total Savings (kW)		
Building Type	Vintage	With CAC	No CAC	Unknown CAC
All	All	0.1272	0.0465	0.1141

NATURAL GAS SAVINGS

$$\Delta Therms^{377} = -\frac{Heating\ Savings * 0.03412}{AFUE}$$

Where:

0.03412 = Converts kWh to therms

AFUE = Efficiency of the furnace

= Actual. If unknown assume 95%[378]

Using default values above the total savings are provided below:

		Total Savings (Therms)		
Building Type	Vintage	Des Moines	Burlington	Mason City
Manufactured	Existing	- 10.8	- 9.6	- 13.7
Manufactured	New	- 7.8	- 6.9	- 9.9
Multifamily	Existing	- 9.0	- 8.0	- 11.4
Multifamily	New	- 6.4	- 5.7	- 8.1
Single-family	Existing	- 10.6	- 9.4	- 13.4
Single-family	New	- 9.2	- 8.2	- 11.6
Residential	Residential	- 10.4		

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

376 Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'..

377 The blower fan is in the heating duct, so all, or very nearly all, of its waste heat is delivered to the conditioned space. This is a negative value, since this measure will increase the heating load due to reduced waste heat.

378 Minimum ENERGY STAR efficiency after 2/1/2012.

GCF = Gas Coincidence Factor for heating[379]

= 0.016525 for Residential Space Heating (other)

Building Type	Vintage	Total Savings (Peak Therms) Des Moines	Burlington	Mason City
Manufactured	Existing	-0.179	-0.159	-0.226
Manufactured	New	-0.129	-0.115	-0.163
Multifamily	Existing	-0.148	-0.132	-0.188
Multifamily	New	-0.106	-0.094	-0.134
Single-family	Existing	-0.175	-0.155	-0.221
Single-family	New	-0.152	-0.135	-0.192
Residential	Residential	-0.172		

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-HVC-FBMT-V03-190101

Sunset Date: 1/1/2020

[379] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.4.6 Geothermal Source Heat Pump

Description

This measure characterizes the installation of an ENERGY STAR qualified Geothermal Source Heat Pump (GSHP) either during new construction or at Time of Sale/Replacement of an existing system(s). Savings are realized due to the GSHP providing heating and cooling more efficiently than the existing or baseline unit, and where a desuperheater is installed, additional Domestic Hot Water (DHW) savings are realized due to displacing existing water heating.

This measure characterizes:

c) Time of Sale:

  ii. The installation of a new residential sized ground source heat pump in place of a new baseline Air Source Heat Pump (ASHP) meeting 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.

d) Early Replacement:

  iii. The early removal of functioning electric heating and cooling (if present) systems from service, prior to the natural end of life, and replacement with a new high efficiency ground source heat pump unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline Air Source Heat Pump and efficient unit consumption for the remainder of the measure life.

  iv. In order to apply Early Replacement savings, the existing unit must be fully operational – providing sufficient space conditioning and/or the cost of repair is under 20% of the new baseline replacement cost (<$471 per ton).

Quality Installation:

Additional savings are attributed to the Quality Installation (QI) of the system. QI programs should follow industry standards such as those described in ANSI ACCA QI5 and QI9vp. This must include considerations of system design (including sizing, matching, ventilation calculations) and equipment installation (including static pressure, airflow, refrigerant charge) and may also consider distribution.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment must be a Geothermal 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

New Construction:

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[380] EER. If a desuperheater is installed, the baseline for DHW savings is assumed to be a Federal Standard electric hot water heater, with Energy Factor calculated as follows[381]:

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

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

If size is unknown, assume 50 gallon; 0.945 EF.

Time of Sale:

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 EER. If a desuperheater is installed, the baseline for DHW savings is assumed to be the existing home's hot water heater fuel and efficiency.

If electric DHW, and unknown efficiency – assume efficiency is equal to pre 4/2015 Federal Standard:

EF = 0.93 – (0.00132 * rated volume in gallons)[382]

If size is unknown, assume 50 gallon; 0.864 EF

If gas water heater, and unknown efficiency – assume efficiency is equal to pre 04/2015 Federal Standard:

EF = (0.67 – 0.0019 * rated volume in gallons)[383].

If size is unknown, assume 40 gallon; 0.594 EF

If DHW fuel is unknown, assume electric DHW provided above.

Early replacement / Retrofit:

The baseline is the efficiency of the *existing* electric heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit and a new baseline Air Source Heat Pump for the remainder of the measure life.

It is assumed that 'Quality Installation' did not occur.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected equipment measure life for Time of Sale or New Construction is assumed to be 25 years[384].

For early replacement, the remaining life of existing equipment is assumed to be 8 years[385].

Quality installation savings are assumed to last the time of the equipment because they come from the selection of fans and ducts, as well as airflow and other settings that do not change through normal operation of the equipment.

DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the Geothermal Source Heat Pump should be used

[380] 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.

[381] 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

[382] Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497.

[383] Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497.

[384] 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 (based on Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007).

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

(default of $3,381 per ton[386]), minus the assumed installation cost of the baseline equipment ($1,867 per ton of capacity[387] for ASHP).

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 Air Source Heat Pump is assumed to be $2,152 per ton[388]. This future cost should be discounted to present value using the nominal societal discount rate.

Quality Installation: The additional design and installation work associated with quality installation has been estimated to add $150 to the installed cost[389].

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RE12 – Residential Single Family Water Heat (Electric)

Loadshape RG07 – Residential Water Heat (Gas)

386 Based on data provided on Home Advisor website, providing national average GSHP costs based on actual project quotes from 132 Home Advisor members and contractors. Equipment and material cost of $2,581 per ton plus an added $800 per ton installation cost, assuming a horizontal loop.

387 Based on data provided on Home Advisor website, providing national average ASHP costs based on actual project quotes from 3,523 Home Advisor members and contractors.

388 The baseline replacement costs is adjusted for 8 years of inflation using inflation rate of 1.91%.

389 Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers, see 'Iowa HVAC Incremental Cost Study' for details.

Algorithm

Calculation of Savings

Electric Energy Savings

Time of sale, New Construction:

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings] + [DHW\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{(EER_{Base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-PL} * (1 - DeratingCool_{eff}))}\right) + FLF_{Cool} * \left(\frac{1}{(EER_{Base} * (1 - DeratingCool_{base}))} - \frac{1}{EER_{EE-FL} * (1 - DeratingCool_{eff}))}\right)\right)}{1000}\right]$$

$$+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{(HSPF_{Base} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-PL} * 3.412 * (1 - DeratingHeat_{eff})))}\right) + FLF_{Heat} * \left(\frac{1}{(HSPF_{Base} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-FL} * 3.412 * (1 - DeratingHeat_{eff})))}\right)\right)}{1000}\right]$$

$$+ \left[\frac{ElecDHW * \%DHWDisp * \frac{1}{EF_{ELEC}} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0}{3412}\right]$$

Early replacement[390]:

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

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings] + [DHW\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{(EER_{Exist} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-PL} * (1 - DeratingCool_{eff}))}\right) + FLF_{Cool} * \left(\frac{1}{(EER_{Exist} * (1 - DeratingCool_{base}))} - \frac{1}{EER_{EE-FL} * (1 - DeratingCool_{eff}))}\right)\right)}{1000}\right]$$

$$+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{(HSPF_{Exist} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-PL} * 3.412 * (1 - DeratingHeat_{eff})))}\right) + FLF_{Heat} * \left(\frac{1}{(HSPF_{Exist} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-FL} * 3.412 * (1 - DeratingHeat_{eff})))}\right)\right)}{1000}\right]$$

[390] 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 that would be the (new base to efficient savings)/(existing to efficient savings).

$$+\left[\frac{ElecDHW * \%DHWDisp * \frac{1}{EF_{ELEC}} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0}{3412}\right]$$

ΔkWH for remaining measure life (next 17 years):

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings] + [DHW\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{(EER_{Base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-PL} * (1 - DeratingCool_{eff}))}\right) + FLF_{Cool} * \left(\frac{1}{(EER_{Base} * (1 - DeratingCool_{base}))} - \frac{1}{EER_{EE-FL} * (1 - DeratingCool_{eff}))}\right)\right)}{1000}\right]$$

$$+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{(HSPF_{Base} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-PL} * 3.412 * (1 - DeratingHeat_{eff})))}\right) + FLF_{Heat} * \left(\frac{1}{(HSPF_{Base} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-FL} * 3.412 * (1 - DeratingHeat_{eff})))}\right)\right)}{1000}\right]$$

$$+\left[\frac{ElecDHW * \%DHWDisp * \frac{1}{EF_{ELEC}} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0}{3412}\right]$$

Where:

$EFLH_{Cool}$ = Equivalent Full Load Hours for cooling

= Dependent on location[391]:

Climate Zone (City based upon)	EFLH$_{Cool}$ (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	548	918	504	736	508	865
Zone 6 (Mason City)	279	468	257	375	259	441
Average/ unknown (Des Moines)	484	811	445	650	449	764

$Capacity_{Cool}$ = Cooling capacity of Geothermal Source Heat Pump (Btu/hr)

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

PLF_{Cool} = Part load cooling mode operation

= 0.85[392] if variable speed GSHP

= 0 if single/constant speed GSHP

FLF_{Cool} = Equivalent full load cooling mode operation factor

= 0.15 if variable speed GSHP

= 1 if single/constant speed GSHP

EER_{Base} = Energy Efficiency Ratio (EER) of new baseline ASHP unit

= 11.8[393]

EER_{Exist} = Energy Efficiency Ratio of existing cooling unit

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

$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$

If SEER rating unavailable use:

Existing Cooling System	EER_{Exist}[394]
Air Source Heat Pump	8.55
Central AC	8.15
No central cooling[395]	Set '1/EER_exist' = 0

391 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

392 Based on Cadmus analysis of the relationship between part- and full-load capacities from building simulations of BEopt (Building Energy Optimization) to generate the energy models. The models were calibrated using Cadmus metered data of 13 high efficiency multi-stage GSHP models functioning in both part- and full-loads.

393 The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

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

395 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.

EER_{EE-PL} = Part load Energy Efficiency Ratio (EER) of GSHP unit

= Actual installed with adjustment for pumping energy[396]:

Adjusted EER (closed loop) = 0.0000315*EER^3 - 0.0111*EER^2 + 0.959*EER
Adjusted EER (open loop) = 0.00005*EER^3 - 0.0145*EER^2 + 0.93*EER

EER_{EE-FL} = Full load Energy Efficiency Ratio (EER) of GSHP unit

= Actual installed with adjustment for pumping energy described above

$DeratingCool_{eff}$ = Efficent GSHP cooling derating

= 0% if Quality Installation is performed

= 10.5% if Quality Installation is not performed[397]

$Derating_{base}$ = Baseline GSHP cooling derating

= 10.5%

$EFLH_{Heat}$ = Equivalent Full Load Hours for heating

= Dependent on location[398]:

Climate Zone (City based upon)	$EFLH_{Heat}$ (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	1,922	2,022	1,389	1,643	1,797	2,137
Zone 6 (Mason City)	2,732	2,874	1,975	2,335	2,554	3,037
Average/ unknown (Des Moines)	2,160	2,272	1,561	1,846	2,019	2,401

$Capacity_{Heat}$ = Full load heating capacity of Geothermal Source Heat Pump (Btu/hr)

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

PLF_{Heat} = Part load heating mode operation

= 0.5[399] if variable speed GSHP

= 0 if single/constant speed GSHP

FLF_{Heat} = Full load heating mode operation factor

= 0.5 if variable speed GSHP

= 1 if single/constant speed GSHP

$HSPF_{Base}$ =Heating System Performance Factor (HSPF) of new replacement baseline heating system (kBtu/kWh)

[396] The methodology provided is based upon REMRate protocol 'Auxiliary Electric Energy of Ground Source Heat Pumps'; http://www.resnet.us/standards/Auxiliary_Electric_Energy_of_Ground_Source_Heat_Pumps_Amendment.pdf
[397] Based on Cadmus assumption in IPL TRM– results in a QI savings that is within a feasible range.
[398] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Heating Degree Day ratios (from NCDC).
[399] Based on Cadmus analysis of the relationship between part- and full-load capacities from building simulations of BEopt (Building Energy Optimization) to generate the energy models. The models were calibrated using Cadmus metered data of 13 high efficiency multi-stage GSHP models functioning in both part- and full-loads.

= 8.2[400]

$HSPF_{Exist}$ = Heating System Performance Factor (HSPF) 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 [401]
Electric Resistance or Electric Furnace	3.41 [402]

$COP_{EE\text{ - }PL}$ = Part load Coefficient of Performance of efficient unit

= Actual Installed with adjustment for pumping energy[403]:

Adjusted COP (closed loop) = 0.000416*COP^3 - 0.041*COP^2 + 1.0086*COP
Adjusted COP (open loop) = 0.00067*COP^3 - 0.0531*COP^2 + 0.976*COP

$COP_{EE\text{ - }FL}$ = Full load Coefficient of Performance of efficient unit

= Actual Installed with adjustment for pumping energy described above

$DeratingHeat_{eff}$ = Efficent GSHP heating derating

= 0% if Quality Installation is performed

= 11.8% if Quality Installation is not performed[404]

$DeratingHeat_{base}$ = Baseline GSHP heating derating

= 11.8%

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

%DHWDisp = Percentage of total DHW load that the GSHP will provide

= Actual if known

= If unknown and if desuperheater installed, assume 44%[405]

= 0% if no desuperheater installed

EF_{ELEC} = Energy Factor (efficiency) of electric water heater. Note if the unit is rated with a Uniform Energy Factor, for version 2.0 of the TRM this will conservatively be applied as

400 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

401 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, IL PY3-PY4 (2010-2012). This estimation methodology appears to provide a result within 10% of actual HSPF.

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

403 The methodology provided is based upon REMRate protocol 'Auxiliary Electric Energy of Ground Source Heat Pumps'; http://www.resnet.us/standards/Auxiliary_Electric_Energy_of_Ground_Source_Heat_Pumps_Amendment.pdf

404 Based on Cadmus assumption in IPL TRM– results in a QI savings that is within a feasible range.

405 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.

an Energy Factor. In version 3.0, these new ratings will be fully incorporated

New Construction = Actual - If unknown, assume federal standard[406]:

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

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

If size is unknown, assume 50 gallon; 0.945EF

Existing Homes = Actual - If unknown, assume pre 4/2015 Federal Standard[407]:

0.93 – (0.00132 * rated volume in gallons)

If size is unknown, assume 50 gallon; 0.864 EF

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[408]

= 17.6

Household = Average number of people per household

Household Unit Type	Household [409]
Manufactured	1.96
Single-Family – Deemed	2.12
Multifamily – Deemed	1.4
Custom	Actual Occupancy or Number of Bedrooms[410]

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{OUT} = Tank temperature

= 126.5°F [411]

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

= 56.5[412]

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

3412 = Conversion from Btu to kWh

406 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

407 Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497.

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

409 Average household size by building type and water heater fuel type based on the 2007 RASS.

410 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.

411 CPUC Residential Retrofit - High Impact Measure Evaluation Report Draft. Dec. 7, 2009. Pg. 76. Average temperature setpoints for two utilities.

412 Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. http://www.nrel.gov/docs/fy10osti/47246.pdf; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

For example, for a 3 ton closed loop GSHP unit with 20 Part Load EER, 18 Full Load EER and 4.4 Part Load COP, 3.4 Full Load COP with desuperheater installed with quality installation with a 50 gallon electric water heater in a new construction single family house in Burlington, IA.:

Adjusted Part Load EER = 0.0000315*20^3 - 0.0111*20^2 + 0.959*20

= 15.0

Adjusted Full Load EER = 0.0000315*18^3 - 0.0111*18^2 + 0.959*18

= 13.8

Adjusted Part Load COP = 0.000416*4.4^3 - 0.041*4.4^2 + 1.0086*4.4

= 3.7

Adjusted Full Load COP = 0.000416*3.4^3 - 0.041*3.4^2 + 1.0086*3.4

= 3.0

ΔkWh = [(548 * 36,000 * ((0.85 * (1/(11.8 * (1-0.105)) – 1/(15 * (1-0)))) + (0.15 * (1/(11.8 * (1-0.105)) – 1/(13.8 * (1-0)))))) / 1000] + [(1922 * 36,000 * ((0.5 * (1/(8.2 * (1-0.118)) – 1/(3.7*3.412 * (1-0)))) + (0.5 * (1/(8.2 * (1-0.118)) – 1/(3.0*3.412 * (1-0)))))) / 1000] + [(1 * 0.44 * 1/0.945 * 17.6 * 2.126 *365.25 * 8.33 * (126.5-56.5) * 1)/3412]

= 535.7 + 3446.7 + 1087.5

= 5,069.9 kWh

For example, for a 3 ton closed loop GSHP unit with 20 Part Load EER, 18 Full Load EER and 4.4 Part Load COP, 3.4 Full Load COP with desuperheater installed without quality installation with a 50 gallon electric water heater in a new construction single family house in Burlington, IA:

ΔkWh = [(548 * 36,000 * ((0.85 * (1/(11.8 * (1-0.105)) – 1/(15 * (1-0.105)))) + (0.15 * (1/(11.8 * (1-0.105)) – 1/(13.8 * (1-0.105)))))) / 1000] + [(1922 * 36,000 * ((0.5 * (1/(8.2 * (1-0.118)) – 1/(3.7*3.412 * (1-0.11.8)))) + (0.5 * (1/(8.2 * (1-0.118)) – 1/(3.0*3.412 * (1-0.118)))))) / 1000] + [(1 * 0.44 * 1/0.945 * 17.6 * 2.126 *365.25 * 8.33 * (126.5-56.5) * 1)/3412]

= 379.3 + 2627.9 + 1087.5

= 4094.7 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale, New Construction:

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-FL} * (1 - DeratingCool_{eff}))} \right)}{1000} \right] * CF$$

Early replacement:

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

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER_{Exist} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-FL} * (1 - DeratingCool_{eff}))} \right)}{1000} \right] * CF$$

ΔkWH for remaining measure life (next 17 years):

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-FL} * (1 - DeratingCool_{eff}))}\right)}{1000}\right] * CF$$

Where:

EERbase = Energy Efficiency Ratio (EER) of new baseline unit

= 11.8[413]

EER_{Exist} = Energy Efficiency Ratio of existing cooling unit

= 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)

If SEER rating unavailable use:

Existing Cooling System	EER_{Exist}[414]
Air Source Heat Pump	8.55
Central AC	8.15
No central cooling[415]	Set '1/EER_exist' = 0

EER_{FL} = Full load Energy Efficiency Ratio (EER) of ENERGY STAR GSHP unit

= Actual with adjustment for pumping energy described above

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

= 0% if Quality Installation is performed and/or if unit is right-sized

= 10.5% if Quality Installation is not performed[416]

$DeratingCool_{base}$ = Baseline Central Air Conditioner Cooling derating

= 10.5%

CF = Summer system peak Coincidence Factor for cooling

= 72%417 for non-QI

= 80%[418] for QI or right sized units

[413] The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

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

[415] 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.

[416] Based on Cadmus assumption in IPL TRM– results in a QI savings that is within a feasible range.

[417] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[418] This higher CF accounts for the demand benefit from right sizing the equipment,

For example, for a 3 ton closed loop GSHP unit with Full Load EER rating of 18 installed with quality installation in a new construction single family house in Burlington, IA:

Adjusted Full Load EER = 0.0000315*18^3 - 0.0111*18^2 + 0.959*18

= 13.8

ΔkW = ((36,000 * (1/(11.8 * (1-0.105)) – 1/(13.8 * (1-0))))/1000) * 0.80

= 0.6401 kW

For example, for a 3 ton closed loop GSHP unit with Full Load EER rating of 18 installed without quality installation in a new construction single family house in Burlington, IA:

ΔkW = ((36,000 * (1/(11.8 * (1-0.105)) – 1/(13.8 * (1-0.105))))/1000) * 0.72

= 0.3557 kW

NATURAL GAS SAVINGS

DHW savings for homes with existing gas hot water:

$$\Delta Therms = [DHW\ Savings]$$

$$= \frac{(1 - ElecDHW) * \%DHWDisp * \frac{1}{EF_{Gas}} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0}{100{,}000}$$

Where:

EF_{GAS} = Energy Factor (efficiency) of gas water heater

New Construction = Actual – If unknown, assume federal standard[419]:

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; 0.615 EF

Existing Homes = Actual – If unknown, assume pre 4/2015 Federal Standard[420]:

(0.67 – 0.0019 * rated volume in gallons)

If size is unknown, assume 40 gallon; 0.594 EF

All other variables provided above

For example, for a 3 ton unit with desuperheater installed with a 40 gallon gas water heater in a new construction single family house in Burlington, IA:

ΔTherms = ((1-0) * 0.44 * 1/0.615 * 17.6 * 2.126 *365.25 * 8.33 * (126.5-56.5) * 1) / 100000

= 57.0 Therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

[419] 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

[420] Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497 http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf

GCF = Gas Coincidence Factor for water heating

= 0.002952 for Residential Water Heating

For example, for a 3 ton unit with desuperheater installed with a 40 gallon gas water heater in a new construction single family house in Burlington, IA:

ΔPeakTherms = 57.0 * 0.002952

= 0.1683 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GSHP-V04-200101

Sunset Date: 1/1/2023

2.4.7 Ductless Heat Pumps

Description

This measure is designed to calculate electric savings for supplementing or replacing existing electric HVAC systems with ductless heat pumps or adding conditioning to a new space. Existing systems can include: electric resistance heating or ducted Air Source Heat Pumps (ASHP). Note this measure does not describe savings from displacement of gas heating. In such circumstances a custom calculation should be performed.

Savings are achieved either by displacing some of the heating or cooling load currently provided by the existing system or adding space conditioning to a new space, and meeting that load with the more efficient ductless heat pump. The offset of the home's heating load is likely for the milder heating periods. The limitations on heating offset increase as the outdoor temperature drops, because the DHP capacity decreases, and the point-source nature of the heater is less able to satisfy heating loads in remote rooms.

For cooling, the proposed savings calculations are aligned with those of typical replacement systems. In most cases, the DHP is expected to replace (rather than offset) a comparable amount of cooling in homes at a much higher efficiency than the previously used cooling.

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.[421]

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

In order for this characterization to apply, baseline equipment must be a permanent electric resistance heating source or a ducted ASHP. Existing cooling equipment is assumed to be standard efficiency. Note that in order to claim cooling savings, there must be an existing air conditioning system.

For adding space conditioning to a new space within a home, for example a new addition, the baseline is assumed to be a baseline ductless heat pump.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 18 years[422].

Deemed Measure Cost

The full installation cost for this measure should be used, if unavailable a default is provided below: [423]

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[421] 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.

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

[423] Cadmus, Opinion Dynamics; 'PY7 HVAC and Ductless Mini-Split Heat Pump Incremental Cost Analysis' memo for Ameren Illinois, dated September 4, 2015.

Unit Capacity (BTU/h)	Equivalent Capacity (tons)	Total Installation Cost
12,000	1.00	$3,051
15,000	1.25	$4,093
18,000	1.50	$5,182
20,000	1.67	$5,897
22,000	1.83	$6,637
24,000	2.00	$7,310
28,000	2.33	$8,209
35,000+	2.92	$10,814

For adding space conditioning to a new space within a home, the incremental cost should be used and is estimated below[424]:

SEER	Incremental Cost
<=18	$346
19	$423
20	$498
21	$577
22	$589
23	$605
24	$621
25	$637
26+	$651

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

2 Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings

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

$$\Delta \text{kWh}_{heat} = \left[\frac{Capacity_{Heat} * EFLH_{Heat} * \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right)}{1000}\right] * LF$$

$$\Delta \text{kWh}_{cool} = \left[\frac{Capacity_{Cool} * EFLH_{cool} * \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right)}{1000}\right] * LF$$

Where:

[424] Costs are estimated based on data from NEEP Phase 2 Incremental Cost Study, 2014. See "DHP Costs_04262017.xls" for details.

$Capacity_{Heat}$ = the heating capacity of the ductless heat pump unit in Btu/hr[425].

= Actual installed

$EFLH_{Heat}$ = Equivalent Full Load Hours for heating

= Dependent on location and application (whole house or add-on/supplementary)[426]:

Application	Climate Zone (City based upon)	EFLH					
		Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Whole house conditioning	Zone 5 (Burlington)	1,922	2,022	1,389	1,643	1,797	2,137
	Zone 6 (Mason City)	2,732	2,874	1,975	2,335	2,554	3,037
	Average/ unknown (Des Moines)	2,160	2,272	1,561	1,846	2,019	2,401
Add-on / supplemental	Zone 5 (Burlington)	1,345	1,415	972	1,150	1,258	1,496
	Zone 6 (Mason City)	1,912	2,012	1,383	1,635	1,788	2,126
	Average/ unknown (Des Moines)	1,512	1,590	1,093	1,292	1,413	1,681

$HSPF_{ee}$ = HSPF rating of new equipment

= Actual installed

$HSPF_{base}$ = HSPF rating of existing or new baseline equipment

= Actual, if unknown assume:

Existing Equipment Type	HSPFbase
Electric resistance heating	3.41[427]
Air Source Heat Pump	5.44[428]
For new space conditioning, assume baseline ductless heat pump	9.1[429]

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr[430].

= Actual installed

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. Depends on location and application (whole house v add-

425 1 Ton = 12 kBtu/hr

426 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Heating Degree Day ratios (from NCDC). Add-on / supplemental EFLH are estimated by multiplying by a factor of 70% (consistent with PA TRM 2013).

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

428 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.

429 Based on average of non-ENERGY STAR qualifying units on AHRI directory. See “AHRI download_0426201.xls” for details.

430 1 Ton = 12 kBtu/hr

on / supplemental). See table below[431].

Application	Climate Zone (City based upon)	$EFLH_{Cool}$[432]					
		Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Whole house conditioning	5 (Burlington)	548	918	504	736	508	865
	6 (Mason City)	279	468	257	375	259	441
	Average/unknown (Des Moines)	484	811	445	650	449	764
Add-on / supplemental	5 (Burlington)	330					
	6 (Mason City)	168					
	Average/unknown (Des Moines)	292					

$SEER_{ee}$ = SEER rating of new equipment

= Actual installed[433]

$SEER_{exist}$ = SEER rating of existing equipment

= Use actual value. If unknown, see table below

Existing Cooling System	SEER_exist
Air Source Heat Pump	9.12
Central AC	8.60[435]
Room AC	8.0[436]
No cooling[437]	Set '1/SEER_exist' = 0
For new space conditioning, assume baseline ductless heat pump	16.6[438]

LF = Load Factor accounting for DHP operating at partial loads and to calibrate savings to findings from evaluations

431 Residential EFLH for room AC

432 EFLH for whole house conditioning are consistent with the Central AC measure (Des Moines EFLH based on Cadmus modeling for the 2011 Joint Assessment and the other locations calculated based on relative Cooling Degree Day ratios (from NCDC)). EFLH for add-on are consistent with Room AC (based on the average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008: http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) to FLH for Central Cooling for the same locations (provided by AHRI: see reference file "ENERGY STARCalc_CAC") is 31%. This factor was applied to the ENERGY STAR FLH for Central Cooling provided for Des Moines, IA to provide an assumption for FLH for Room AC, and adjusted by CDD for the other locations.)

433 Note that if only an EER rating is available, a conversion factor of SEER=1.1*EER can be used

434 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren IL PY3-PY4 (2010-2012). The utilities should collect this information if possible to inform a future update.

435 Ibid.

436 Estimated by converting the EER assumption using the conversion equation; EER_base = (-0.02 * SEER_base^2) + (1.12 * SEER). From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

437 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.

438 Based on average of non-ENERGY STAR qualifying units on AHRI directory. See "AHRI download_0426201.xls" for details.

= 25%[439]

For example, installing a 1.5-ton (heating and cooling capacity) ductless heat pump unit rated at 10 HSPF and 18 SEER in a single-family home in Des Moines to displace electric baseboard heat load and replace a window air conditioner, savings are:

ΔkWh_{heat}	= ((18000 * 2272 * (1/3.41 – 1/10)) / 1000) * 0.25	= 1975.8 kWh
ΔkWh_{cool}	= ((18000 * 292 * (1/8 – 1/18))/1000) * 0.25	= 91.3 kWh
ΔkWh	= 1975.8 + 91.3	= 2,067kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{EER_{exist}} - \frac{1}{EER_{ee}} \right) * CF}{1000} \right]$$

Where:

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

= Use actual EER rating otherwise:

Existing Cooling System	EER_exist
Air Source Heat Pump	8.55
Central AC	8.15[441]
Room AC	7.7 [442]
No central cooling[443]	Set '1/EER_exist' = 0
For new space conditioning, assume baseline ductless heat pump	10.0[444]

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:

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

CF = Summer System Peak Coincidence Factor for Cooling

For supplemental or limited zonal cooling = 43.1%[445]

For whole house cooling = 72%[446]

---

439 Factor used by Cadmus, and supported by findings in Cadmus "Ductless Mini-Split Heat Pump Impact Evaluation", December 30, 2016.

440 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 program. The utilities should collect this information if possible to inform a future update.

441 Ibid.

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

443 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.

444 Based on average of non-ENERGY STAR qualifying units on AHRI directory. See "AHRI download_0426201.xls" for details.

445 Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

446 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

NATURAL GAS SAVINGS

Note this measure does not describe savings from displacement of gas heating. In such circumstances a custom calculation should be performed.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-DSHP-V03-200101

SUNSET DATE: 1/1/2024

2.4.8 Energy Recovery Ventilator

DESCRIPTION

An energy recovery ventilator saves energy in a home ventilation system by preconditioning incoming air with heated or cooled exhaust air before it is ventilated outside. An ERV is capable of transferring both sensible and latent heat loads. This measure includes the addition of energy recovery equipment on the HVAC system of a newly constructed home. This measure analyzes the heating and cooling savings potential from recovering energy from exhaust air.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is a mechanical ventilation system outfitted with an energy recovery ventilator.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a mechanical ventilation system without energy recovery capabilities.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the domestic energy recovery equipment is 15 years.[447]

DEEMED MEASURE COST

The actual install cost (including labor) for this measure should be used, if unknown use $1050[448].

DEEMED O&M COST ADJUSTMENTS

There are no expected O&M savings associated with this measure, as compared to the O&M costs of a mechanical ventilation system.

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RE07 – Residential Single Family Cooling

Loadshape RG01 – Residential Boiler

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RG04 – Residential Other Heating

[447] Assumed service life limited by controls -" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy

[448] The average of $800 and $1100, the costs associated with average and high efficiency ERVs as per the Minnesota Sustainable Housing Initiative http://www.mnshi.umn.edu/kb/scale/hrverv.html. $100 was added for incremental installation labor costs.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

ΔkWh_cooling = If central cooling, reduction in annual cooling load due to ERV recovery

For units with cooling capacities less than 65 kBtu/hr:

$$\Delta kWh_{cooling} = \left[\frac{EFLH_{cool} * Capacity_{Cool} * \left(\frac{1}{SEER_{exist}}\right)}{1000}\right] * RF_{cool}$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWh_{cooling} = \left[\frac{EFLH_{cool} * Capacity_{Cool} * \left(\frac{1}{IEER_{exist}}\right)}{1000}\right] * RF_{cool}$$

Where:

$EFLH_{cool}$ = Equivalent Full load cooling hours

= Dependent on location[449]:

Climate Zone (City based upon)	$EFLH_{cool}$ (Hours)	
	Single Family New	Manufactured New
Zone 5 (Burlington)	548	508
Zone 6 (Mason City)	279	259
Average/ unknown (Des Moines)	484	449

$Capacity_{Cool}$ = Cooling Capacity of equipment in Btu/hr (note 1 ton = 12,000Btu/hr)

= Actual installed

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

= Actual installed

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

= Actual installed

1000 = Converts Btu to kBtu

RF_{cool} = Recovery factor, expressed as a percentage of total design load reduction for cooling

[449] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

= 9%[450]

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to ERV recovery

$$\Delta kWh_{heating} = \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{HSPF_{exist}}\right)}{1000}\right] * RF_{heat}$$

Where:

$EFLH_{Heat}$ = Equivalent Full load hours of heating

= Dependent on location[451]:

Climate Zone (City based upon)	$EFLH_{Heat}$ (Hours)	
	Single Family New	Manufactured New
Zone 5 (Burlington)	1922	1797
Zone 6 (Mason City)	2732	2554
Average/ unknown (Des Moines)	2160	2019

$Capacity_{Heat}$ = Heating Capacity of equipment in (Btu/hr)

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

$HSPF_{Exist}$ = Heating System Performance Factor of existing heating system (kBtu/kWh)

= Actual. Note: resistance heat will have an HSPF of 3.412 [452]

1000 = Converts Btu to kBtu

RF_{heat} = Recovery factor, expressed as a percentage of total design load reduction for heating

= 10%[453]

For example, an ERV installed in a new single family home in Mason City with 3 ton 16 SEER, 12.5 EER, 9 HSPF ducted air source heat pump.

$\Delta kWh_{cooling}$ = ((279 * 36,000 * (1/16))/1000) * 0.09

= 56.5 kWh

$\Delta kWh_{heating}$ = ((2732 * 36,000 * (1/9))/1000) * 0.10

= 1092.8 kWh

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

= 56.5 + 1092.8

=1149.3 kWh

450 Based on modeling performed for the Minnesota Sustainable Housing Initiative. Results obtained using REM Rate 12.3 based on an 864sf Minnesota code base house, with wood siding, 15% window-to-floor area, window U-value 0.33 and SHGC 0.3, 80 AFUE furnace, and 10 EER air conditioning. Value is assumed to be reasonably applicable for a home in Iowa.

451 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Heating Degree Day ratios (from NCDC).

453 Based on modeling performed for the Minnesota Sustainable Housing Initiative. Results obtained using REM Rate 12.3 based on an 864sf Minnesota code base house, with wood siding, 15% window-to-floor area, window U-value 0.33 and SHGC 0.3, 80 AFUE furnace, and 10 EER air conditioning. Value is assumed to be reasonably applicable for a home in Iowa.

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh\_cooling}{EFLH_{cool}} * CF$$

Where:

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP[454]

Other factors as defined above.

> **For example,** an ERV installed in a new single family home in Mason City with 3 ton 16 SEER, 12.5 EER, 9 HSPF ducted air source heat pump.
>
> ΔkW = 56.5/279 * 0.68
>
> = 0.1377 kW

Natural Gas Savings

ΔTherms (if Natural Gas heating)

$$\Delta Therms = \frac{EFLH_{GasHeat} * Capacity_{Heat}}{\eta_{Heat} * 100{,}000} * RF_{heat}$$

Where:

$EFLH_{GasHeat}$ = Equivalent Full load heating hours

= Dependent on location[455]:

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	766	883	534	750	651	904
Zone 6 (Mason City)	1090	1253	759	1065	926	1284
Average/ unknown (Des Moines)	861	991	601	842	732	1015

η_{Heat} = Efficiency of heating system

= Actual[456]

100,000 = Converts Btu to Therms

Other factors as defined above.

[454] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[455] Full load hours for Des Moines are based on analysis performed by Tetra Tech in April, 2018. Tetra Tech gathered MidAmerican program data from two residential programs with installs between October 2012 to December 2016, and matched them with gas meter consumption data following the install. Regression models were performed to estimate the Normalized Annual Heating (NAH) consumption. EFLH is then estimated by dividing NAH by the units capacity. See "Res Furnace EFLH Findings_30April2018.ppt" for more information. The resulting value of 991 hours for a single family existing home in Des Moines is scaled to other building types using the relative assumptions based upon the Cadmus modeling exercise performed for the 2011 Joint Assessment, and to other climate zones based on relative Heating Degree Day ratios (from NCDC).

[456] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

For example, an ERV installed in a new single family home in Mason City with 90,000Btu, 95% AFUE gas furnace.

ΔTherms = ((1090 * 90,000) / (0.95 * 100,000)) * 0.10

= 103.3 Therms

Peak Gas Savings

$$\Delta\text{PeakTherms} = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[457]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, an ERV installed in a new single family home in Mason City with 90,000Btu, 95% AFUE gas furnace.

ΔTherms = 103.3 * 0.016525

= 1.707 Therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-HVC-ERVE-V03-190101

Sunset Date: 1/1/2022

[457] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.4.9 Gas Fireplace

Description

This measure characterizes the energy savings from the installation of a new gas fireplace with a 70% AFUE.

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

Definition of Efficient Equipment

The criterion for this measure is a heat rated gas fireplace with 70%+ AFUE, intermittent ignition, and thermostatic control with blower.

Definition of Baseline Equipment

The baseline equipment is a gas fireplace with <64% AFUE[458].

Deemed Lifetime of Efficient Equipment

The expected measure life of a gas fireplace is assumed to be 20 years[459].

Deemed Measure Cost

For retrofits, actual material and labor costs should be used. For time of sale and new construction, actual costs may be used if associated baseline costs can also be estimated for the application. If actual costs are unknown, the incremental equipment cost of this measure is $244 and the incremental installation cost is $18. Total incremental cost is $262[460].

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

$$\Delta Therms = Capacity_{\,output} * \left(\frac{1}{eff_b} - \frac{1}{eff_e}\right) * Hours\ of\ Use * 0.01$$

Where:

458 "Direct Heating Equipment: Market Technology and Characterization," *Consortium for Energy Efficiency*, January, 2011.
459 *InterNachi's Standard Estimated Life Expectancy Chart for Homes.* .International Association of Certified Home Inspectors. https://www.nachi.org/life-expectancy.htm. Accessed January 21, 2016.
460 Incremental costs developed through linear extrapolation from incremental costs provided in "Direct Heating Equipment: Market and Technology Characterization," *Consortium for Energy Efficiency*, January 2011. Tables 5 and 6.

$Capacity_{output}$ = Output Capacity in kBTU

= Actual, if unknown assume 37kBtu

eff_b = Efficiency of baseline equipment

= 64%

eff_e = Efficiency of new unit

= Actual, if unknown assume 70%

$Hours\ of\ Use$ = 135[461]

0.01 = Conversion factor kBtu to Therms

Using default assumptions, deemed savings is:

ΔTherms = 37 * (1/0.64 – 1/0.70) * 135 * 0.01

= 6.7 Therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[462]

= 0.016525 for Residential Space Heating (other)

Using default assumptions, deemed savings is:

ΔPeakTherms = 6.7 * 0.016525

= 0.1107 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GASF-V02-180101

SUNSET DATE: 1/1/2023

[461] This value was calculated using the data available on the website that a typical fireplace is used 52 times a year and with an average usage time of 2.6 hours. https://www.hpba.org/Resources/PressRoom/ID/79/2011-State-of-the-Hearth-Industry-Report

[462] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.4.10 Whole House Fan

Description

A whole house fan can be a simple and inexpensive method of cooling a house. During shoulder seasons, it is possible to reduce or even eliminate the need for air conditioning by operating the fans during periods when outside air is cooler than that inside a home. The fan draws cool outdoor air inside through open windows and exhausts hot indoor air through the attic to the outside. As temperatures rise during the daytime, the fan is turned off and windows are shut to allow the home to "coast" through the hottest part of the day, reducing or eliminating the need for supplemental air conditioning.

The use of timers or thermostatic controls is highly recommended to safeguard against situations that could result in increased energy consumption. For example, prolonged operation of the fan, long after the temperature inside the house has been equalized to temperatures outside could potentially create a situation where more energy is used than would have been by an air conditioning unit.

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

Definition of Efficient Equipment

The efficient condition is a home equipped with a whole house fan. A whole house fan is distinct from an exhaust fan, which may be intended to ventilate specific areas of a home. Whole house fans are installed in the attic and sized to provide 30 to 60 air changes per hour throughout the entire home.

Definition of Baseline Equipment

The baseline condition is a home without a whole house fan that operates an air conditioner during shoulder seasons and periods.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 25 years.[463]

Deemed Measure Cost

For all project types, full installation costs should be used for screening purposes.

Loadshape

RE11: Residential Single Family Vent.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Electric energy savings are deemed based on building type and vintage[464]:

Building Type	Vintage	Annual Energy Savings kWh
Manufactured	Existing	284
Manufactured	New	155

[463] 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.

[464] Inferred from the 2011 Assessment of Potential [IPL], deemed based on 15% savings of CAC/ASHP system from shoulder periods. These values should be reevaluated if there is significant uptake in this measure.

Building Type	Vintage	Annual Energy Savings kWh
Single Family	Existing	343
Single Family	New	197

Summer Coincident Peak Demand Savings

There are no coincident peak demand savings expected for this measure.

Natural Gas Savings

N/A

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-HVC-WHF-V02-190101

Sunset Date: 1/1/2023

2.4.11 Central Air Source Heat Pump Tune-Up

Description

This measure is for the tune-up of a central Air Source Heat Pump (ASHP). The tune-up will improve heat pump performance by inspecting, cleaning, and adjusting the heat pump for correct and efficient operation.

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 refers to tune-ups through the HVAC SAVE program and requires certified technicians adhering to all of the requirements of the program. The following are key activities that are provided through an HVAC SAVE program beyond those of a routine annual maintenance[465]:

- Measure pressure drops at return, filter, coil, and supply.
- Determine equipment air flow using OEM blower data or measuring.
- Measure temperature difference (DB, RH or WB) across equipment.
- Determine the OEM's current capacity rating from expanded tables.
- 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.
- Calibrate refrigerant charge.
- Complete final test-out, compare before and after.

Definition of Baseline Equipment

The baseline is a residential heat pump (≤ 65,000 Btu/hr) that was installed without Quality Installation and has not already received an HVAC SAVE tune-up.

Deemed Lifetime of Efficient Equipment

The measure life of an HVAC SAVE tune-up is the remaining life of the equipment, assume 9 years (half the new ASHP measure life.)

Deemed Measure Cost

The incremental cost for this measure should be the actual cost of tune-up.

Loadshape

Loadshape RE08 – Residential Single Family Heat Pump

Algorithms

Calculation of Energy Savings

Electric Energy Savings

The HVAC SAVE protocol results in a number of outputs including the measured output capacity of the unit (btuh).

[465] As provided in ANSI approved ACCA 4 specification for Quality Maintenance.

The following algorithm utilizes these outputs to adjust the EFLH of the post tune-up condition to calculate as site specific savings estimate. There are two limits imposed to using these outputs directly:

1. The post efficiency in EER (i.e., measured output (Btuh)/rated input (Wh)) must not exceed the rated efficiency of the unit. Where the test results indicates an efficiency greater than the rated efficiency, the measured output should be adjusted to equal the value at the rated efficiency,
2. A limit of 15% savings of pre tune-up consumption is applied. Where outputs indicate savings higher than 15%, the program should claim savings at 15%, unless a higher level of independent review is able to justify the higher level of savings.

Note, if a program prefers, a deemed savings percentage can be applied and this is provided as an alternative below.

$$\Delta kWh = (CoolConsumptionPre - CoolConsumptionPost) + (HeatConsumptionPre - HeatConsumptionPost)$$

$$\Delta kWh = \left[\frac{\left(EFLH_{cool} * \frac{RatedCapacity_{Cool}}{RatedSEER}\right) - \left(EFLH_{cool} * \frac{CAPOutputCool_{Pre}}{CAPOutputCool_{Post}} * \frac{RatedCapacity_{Cool}}{RatedSEER}\right)}{1000}\right] + \left[\frac{\left(EFLH_{Heat} * \frac{RatedCapacity_{Heat}}{RatedHSPF}\right) - \left(EFLH_{Heat} * \frac{CAPOutputHeat_{Pre}}{CAPOutputHeat_{Post}} * \frac{RatedCapacity_{Heat}}{RatedHSPF}\right)}{1000}\right]$$

If using deemed savings percentage:

$$\Delta kWh = \left[\frac{EFLH_{cool} * RatedCapacity_{Cool} * \left(\frac{SF_{cool}}{RatedSEER}\right)}{1000}\right] + \left[\frac{EFLH_{Heat} * RatedCapacity_{Heat} * \left(\frac{SF_{heat}}{RatedHSPF}\right)}{1000}\right]$$

Where:

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

= Dependent on location[466]:

Climate Zone (City based upon)	$EFLH_{cool}$ (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

$RatedCapacity_{Cool}$ = Rated Cooling Capacity of Air Source Heat Pump (Btu/hr)

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

SF_{cool} = Cooling Savings Factor for ASHP tune-ups

[466] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from National Climatic Data Center, NCDC).

=7.5% [467]

RatedSEER = Rated Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

= Actual

SF_{heat} = Heating Savings Factor for ASHP tune-ups

=2.3% [468]

$CAPOutputCool_{Pre}$ = Measured Output Cooling Capacity before HVAC SAVE tune-up (btuh)

$CAPOutputCool_{Post}$ = Measured Output Cooling Capacity after HVAC SAVE tune-up (btuh)

$EFLH_{Heat}$ = Equivalent Full load hours of heating

= Dependent on location[469]:

Climate Zone (City based upon)	$EFLH_{Heat}$ (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	2022	1643	2137
Zone 6 (Mason City)	2874	2335	3037
Average/ unknown (Des Moines)	2272	1846	2401

$RatedCapacity_{Heat}$ = Rated Heating Capacity of Air Source Heat Pump (Btu/hr)

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

RatedHSPF = Rated Heating System Performance Factor of existing heating system (kBtu/kWh)

= Actual

$CAPOutputHeat_{Pre}$ = Measured Output Heating Capacity before HVAC SAVE tune-up (btuh)

$CAPOutputHeat_{Post}$ = Measured Output Heating Capacity after HVAC SAVE tune-up (btuh)

For example, for a two ton, 14 SEER, 12 EER, 9 HSPF air source heat pump undergoing an HVAC SAVE tune-up in an existing single family home in Des Moines with the following outputs; $CAPOutputCool_{Pre}$ = 16,484 btuh, $CAPOutputCool_{Post}$ = 21,745 btuh, $CAPOutputHeat_{Pre}$ = 22,800 btuh, $CAPOutputHeat_{Post}$ = 23,500 btuh:

ΔkWh = (((811 * 24,000/14) – (811 * 16,484/21,745 * 24,000/14)) + ((2,272 * 24,000/9) – (2,272 * 22,800/23,500 * 24,000/9)))/1,000

= 336 + 180

= 517 kWh

[467] Calculated based on Cadmus report: Savings percent for a refrigerant charged AC unit, Bin Analysis, Energy Savings Impact of Improving the Installation of Residential Central Air Conditioners, 2005

[468] Calculated based on Cadmus report: Savings percent for a refrigerant charged AC unit, Bin Analysis, Energy Savings Impact of Improving the Installation of Residential Central Air Conditioners, 2005

[469] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Heating Degree Day ratios (from NCDC).

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\left[\frac{RatedCapacity_{Cool}}{RatedEER * 1000} \right] - \left[\frac{RatedCapacity_{Cool} * \frac{CAPOutputCool_{Pre}}{CAPOutputCool_{Post}}}{RatedEER * 1000} \right] \right) * CF$$

If using deemed savings percentage:

$$\Delta kW = \left[\frac{RatedCapacity_{Cool} * \left(\frac{SF_{cool}}{RatedEER} \right)}{1000} \right] * CF$$

Where:

RatedEER = Rated 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^2) + (1.12 * SEER)

CF = Summer System Peak Coincidence Factor for Cooling

= 72%[470]

For example, for a two ton, 14 SEER, 12 EER, 9 HSPF air source heat pump undergoing an HVAC SAVE tune-up in an existing single family home in Des Moines with the following outputs: $CAPOutputCool_{Pre}$ = 16,484 Btuh, $CAPOutputCool_{Post}$ = 21,745 Btuh:

ΔkW = ((24,000/(12 * 1000)) – ((24,000 * 16,484/21,745)/(12 * 1000))) * 72%

= 0.348 kW

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

While there are likely to be some O&M cost savings due to reduced service calls, increased equipment life, etc., these will only be realized with a regular maintenance schedule, which cannot be assumed for each individual tune-up measure. This benefit is therefore conservatively excluded.

MEASURE CODE: RS-HVC-ATUN-V03-190101

SUNSET DATE: 1/1/2020

[470] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

2.4.12 Central Air Conditioner Tune-Up

Description

This measure is for the tune-up of a Central Air Conditioner. The tune-up will improve performance by inspecting, cleaning, and adjusting the system for correct and efficient operation.

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 refers to tune-ups through the HVAC SAVE program and requires certified technicians adhering to all of the requirements of the program. The following are key activities that are provided through an HVAC SAVE program beyond those of a routine annual maintenance[471]:

- Measure pressure drops at return, filter, coil, and supply.
- Determine equipment air flow using OEM blower data or measuring.
- Measure temperature difference (DB, RH or WB) across equipment.
- Determine the OEM's current capacity rating from expanded tables.
- 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.
- Calibrate refrigerant charge.
- Complete final test-out, compare before and after.

Definition of Baseline Equipment

The baseline is a central air conditioner with a capacity up to 135,000 Btu/hr that was installed without Quality Installation and has not already received an HVAC SAVE tune-up.

Deemed Lifetime of Efficient Equipment

The measure life of an HVAC SAVE tune-up is the remaining life of the equipment, assume 9 years (half the new CAC measure life.)

Deemed Measure Cost

The incremental cost for this measure should be the actual cost of tune-up.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE02 – Residential Multifamily Cooling

[471] As provided in ANSI approved ACCA 4 specification for Quality Maintenance.

Algorithms

Calculation of Energy Savings

Electric Energy Savings

The HVAC SAVE protocol results in a number of outputs including the measured output capacity of the unit (btuh).

The following algorithm utilizes these outputs to adjust the EFLH of the post tune-up condition to calculate as site specific savings estimate. There are two limits imposed to using these outputs directly:

1. The post efficiency in EER (i.e. measured output (Btuh)/rated input (Wh)) must not exceed the rated efficiency of the unit. Where the test results indicates an efficiency greater than the rated efficiency, the measured output should be adjusted to equal the value at the rated efficiency,
2. A limit of 15% savings of pre tune-up consumption is applied. Where outputs indicate savings higher than 15%, the program should claim savings at 15%, unless a higher level of independent review is able to justify the higher level of savings.

Note, if a program prefers, a deemed savings percentage can be applied and this is provided as an alternative below.

$$\Delta kWh = (CoolConsumptionPre - CoolConsumptionPost)$$

For units with cooling capacities less than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{\left(EFLH_{cool} * \frac{RatedCapacity_{Cool}}{RatedSEER}\right) - \left(EFLH_{cool} * \frac{CAPOutputCool_{Pre}}{CAPOutputCool_{Post}} * \frac{RatedCapacity_{Cool}}{RatedSEER}\right)}{1000}\right]$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{\left(EFLH_{cool} * \frac{RatedCapacity_{Cool}}{RatedIEER}\right) - \left(EFLH_{cool} * \frac{CAPOutputCool_{Pre}}{CAPOutputCool_{Post}} * \frac{RatedCapacity_{Cool}}{RatedIEER}\right)}{1000}\right]$$

If using deemed savings percentage:

For units with cooling capacities less than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * RatedCapacity_{Cool} * \left(\frac{SF_{cool}}{RatedSEER}\right)}{1000}\right]$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * RatedCapacity_{Cool} * \left(\frac{SF_{cool}}{RatedIEER}\right)}{1000}\right]$$

Where:

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

= Dependent on location[472]:

[472] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from National Climatic Data Center, NCDC).

Climate Zone (City based upon)	$EFLH_{cool}$ (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

$RatedCapacity_{Cool}$ = Rated Cooling Capacity (Btu/hr)

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

SF_{cool} = Cooling Savings Factor for CAC tune-ups

=7.5% [473]

RatedSEER = Rated Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

= Actual

RatedIEER = Rated Integrated Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

= Actual

$CAPOutputCool_{Pre}$ = Measured Output Cooling Capacity before HVAC SAVE tune-up (Btuh)

$CAPOutputCool_{Post}$ = Measured Output Cooling Capacity after HVAC SAVE tune-up (Btuh)

For example, for a three ton, 15 SEER, 12 EER central air conditioner undergoing an HVAC SAVE tune-up in a single family home in Des Moines with the following outputs; $CAPOutputCool_{Pre}$ = 30,500 Btuh, $CAPOutputCool_{Post}$ = 34,800 Btuh:

ΔkWh = ((811 * 36,000/15) – (811 * 30,500/34,800 * 36,000/15)) / 1,000

= 241 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\left[\frac{RatedCapacity_{Cool}}{RatedEER * 1000}\right] - \left[\frac{RatedCapacity_{Cool} * \frac{CAPOutputCool_{Pre}}{CAPOutputCool_{Post}}}{RatedEER * 1000}\right]\right) * CF$$

If using deemed savings percentage:

$$\Delta kW = \left[\frac{RatedCapacity_{Cool} * \left(\frac{SF_{cool}}{RatedEER}\right)}{1000}\right] * CF$$

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:

[473] Calculated based on Cadmus report: Savings percent for a refrigerant charged AC unit, Bin Analysis, Energy Savings Impact of Improving the Installation of Residential Central Air Conditioners, 2005

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

CF = Summer System Peak Coincidence Factor for Cooling

= 68%[474]

For example, for a three ton, 15 SEER, 12 EER, central air conditioner undergoing an HVAC SAVE tune-up in a single family home in Des Moines with the following outputs; $CAPOutputCool_{Pre}$ = 30,500 Btuh, $CAPOutputCool_{Post}$ = 34,800 Btuh:

ΔkW = ((36,000/(12 * 1000)) – ((36,000 * 30,500/34,800)/(12 * 1000))) * 68%

= 0.252 kW

Water Impact Descriptions and Calculation

N/A

O&M Cost Adjustment Calculation

While there are likely to be some O&M cost savings due to reduced service calls, increased equipment life, etc., these will only be realized with a regular maintenance schedule, which cannot be assumed for each individual tune-up measure. This benefit is therefore conservatively excluded.

Measure Code: RS-HVC-CTUN-V03-190101

Sunset Date: 1/1/2020

[474] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'..

2.4.13 Boiler Tune-up

Description

This measure is for a residential boiler that provides space heating. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Components of tune-up: adjust air flow and reduce excessive stack temperatures; adjust burner and gas input; check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

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 recommended tune-up requirements are listed below. It is recommended that utility programs require that technicians performing the work are appropriately certified.

- Measure combustion efficiency using an electronic flue gas analyzer.
- Adjust airflow and reduce excessive stack temperatures.
- Adjust burner and gas input, manual or motorized draft control.
- Check for proper venting.
- Complete visual inspection of system piping and insulation.
- Check safety controls.
- Check adequacy of combustion air intake.
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel.

Definition of Baseline Equipment

The baseline condition of this measure is a boiler that has not had a tune-up within the past 12 months

Deemed Lifetime of Efficient Equipment

The life of this measure is 1 year.

Deemed Measure Cost

The cost of this measure is the actual tune-up cost.

Loadshape

Loadshape RG01 – Residential Boiler

Algorithm

Calculation of Energy Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

N/A

Natural Gas Savings

$$\Delta Therms = \frac{Capacity * EFLH * \left(\frac{(Effbefore + Ei)}{Effbefore} - 1\right)}{100{,}000}$$

Where:

Capacity = Boiler gas input size (Btu/hr)

= Actual

EFLH =Equivalent Full Load Hours for heating

= Dependent on location[475]:

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	766	883	534	750	651	904
Zone 6 (Mason City)	1090	1253	759	1065	926	1284
Average/ unknown (Des Moines)	861	991	601	842	732	1015

[475] Full load hours for Des Moines are based on analysis performed by Tetra Tech in April, 2018. Tetra Tech gathered MidAmerican program data from two residential programs with installs between October 2012 to December 2016, and matched them with gas meter consumption data following the install. Regression models were performed to estimate the Normalized Annual Heating (NAH) consumption. EFLH is then estimated by dividing NAH by the units capacity. See "Res Furnace EFLH Findings_30April2018.ppt" for more information. The resulting value of 991 hours for a single family existing home in Des Moines is scaled to other building types using the relative assumptions based upon the Cadmus modeling exercise performed for the 2011 Joint Assessment, and to other climate zones based on relative Heating Degree Day ratios (from NCDC).

Effbefore = Combustion efficiency of the boiler before the tune-up[476]

= Actual

Ei = Combustion efficiency Improvement of the boiler tune-up measure

= Actual

100,000 = Converts Btu to therms

For example, for a 100 kBtu boiler in a Des Moines single family house that records an efficiency prior to tune-up of 82% AFUE and has a 1.8% improvement in efficiency after tune-up:

Δtherms = (100,000 * 991 * (((0.82 + 0.018)/ 0.82) – 1)) /100,000

= 21.8 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[477]

= 0.014378 for Residential Boiler

For example, for a 100 kBtu boiler in a Des Moines single family house that records an efficiency prior to tune up of 82% AFUE and has a 1.8% improvement in efficiency after tune up:

ΔPeakTherms = 21.8 * 0.014378

= 0.3134 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

While there are likely to be some O&M cost savings due to reduced service calls, increased equipment life, etc., these will only be realized with a regular maintenance schedule, which cannot be assumed for each individual tune-up measure. This benefit is therefore conservatively excluded.

MEASURE CODE: RS-HVC-BLRT-V02-190101

SUNSET DATE: 1/1/2023

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[476] The percentage improvement in combustion efficiency is deemed a reasonable proxy for the system improvement. If a full thermal efficiency test is performed instead, that should be used.

[477] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.4.14 Furnace Tune-Up

Description

This measure is for the tune-up of a natural gas Residential furnace. 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

The recommended tune-up requirements are listed below. It is recommended that utility programs require that technicians performing the work are appropriately certified.

- 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 recommendations.
- 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 that thermostat operation is per manufacturer's recommendations (if adjustments are 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.

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 maintenance program[478]:

- 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.
- Determine on-rate for a furnace by clocking the clock 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.

[478] As provided in ANSI approved ACCA 4 specification for Quality Maintenance.

- Adjust/modify gas pressure and venting to OEM specifications.
- Complete final test-out, compare before and after

Definition of Baseline Equipment

The baseline for a clean and check tune-up is a 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. However subsequent clean and check tune-ups can be performed.

Deemed Lifetime of Efficient Equipment

The measure life of a clean and check tune-up is 2 years[479].

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.

Loadshape

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RG04 – Residential Other Heating

Algorithms

Calculation of Energy Savings

Electric Energy Savings

$$\Delta kWh = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = as calculated below

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

= 3.14%[480]

29.3 = kWh per therm

Summer Coincident Peak Demand Savings

N/A

Natural Gas Savings

1. HVAC SAVE Tune-up Programs:

The HVAC SAVE protocol results in a number of outputs including the measured output capacity of the unit (Btuh), and the adjusted input capacity (Btuh) by recording the gas meter.

[479] Based on VEIC professional judgment.

[480] 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.

The following algorithm utilizes these outputs to adjust the EFLH of the pre tune-up condition (since the EFLH correspond to a post HVAC SAVE condition) to calculate as site specific savings estimate. There are two limits imposed to using these outputs directly:

1. The post efficiency (i.e., measured output/adjusted input) must not exceed the rated efficiency of the unit. Where the test results indicates an efficiency greater than the rated efficiency, the measured output should be adjusted to equal the value at the rated efficiency.
2. A limit of 15% savings of pre tune-up consumption is applied. Where outputs indicate savings higher than 15%, the program should claim savings at 15%, unless a higher level of independent review is able to justify the higher level of savings.

Note, if a program prefers, a deemed savings percentage can be applied and this is provided as an alternative below.

$$\Delta Therms = ConsumptionPre - ConsumptionPost$$

$$\Delta Therms = \frac{\left(\left(CAPInput_{Pre} * EFLH \ * \left(\frac{CAPOutput_{Post}}{CAPOutput_{Pre}}\right)\right) - \left(CAPInput_{Post} * \ EFLH\right)\right)}{100{,}000}$$

If using deemed savings percentage:

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

Where:

CAPInput = Gas Furnace input capacity (Btuh)

= Actual rated capacity

$CAPInput_{Pre}$ = Gas Furnace input capacity pre tune-up (Btuh)

= Measured input capacity from HVAC SAVE

$CAPInput_{Post}$ = Gas Furnace input capacity post tune-up (Btuh)

= Measured input capacity from HVAC SAVE

EFLH =Equivalent Full Load Hours for heating

= Dependent on location[481]:

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	766	883	534	750	651	904
Zone 6 (Mason City)	1090	1253	759	1065	926	1284
Average/ unknown (Des Moines)	861	991	601	842	732	1015

[481] Full load hours for Des Moines are based on analysis performed by Tetra Tech in April, 2018. Tetra Tech gathered MidAmerican program data from two residential programs with installs between October 2012 to December 2016, and matched them with gas meter consumption data following the install. Regression models were performed to estimate the Normalized Annual Heating (NAH) consumption. EFLH is then estimated by dividing NAH by the units capacity. See "Res Furnace EFLH Findings_30April2018.ppt" for more information. The resulting value of 991 hours for a single family existing home in Des Moines is scaled to other building types using the relative assumptions based upon the Cadmus modeling exercise performed for the 2011 Joint Assessment, and to other climate zones based on relative Heating Degree Day ratios (from NCDC).

$CAPOutput_{Pre}$ = Measured Output Capacity before HVAC SAVE tune-up (Btuh)

$CATOutput_{Post}$ = Measured Output Capacity after HVAC SAVE tune-up (Btuh)

AFUE = Existing Furnace Annual Fuel Utilization Efficiency Rating

= Actual

$Derating_{eff}$ = Furnace AFUE Derating after HVAC SAVE tune-up

= 0%

$Derating_{base}$ = Furnace AFUE Derating before HVAC SAVE tune-up

= 6.4%[482]

100,000 = Converts Btu to therms

For example, for a furnace tune-up in the HVAC SAVE program in a Des Moines single family house with the following outputs: $CAPInput_{Pre}$ = 56,250 Btuh, $CAPInput_{Post}$ = 56,250 Btuh, $CAPOutput_{Pre}$ = 44,390 Btuh, $CAPInput_{Post}$ = 51,224 Btu.

ΔTherms = ((56,250 * 991 * (51,224/44,390)) – (56,250 * 991)) /100,000

= 85.8 therms

2. Other Tune-up Programs:

$$\Delta Therms = \frac{CAPInput * EFLH * \left(\frac{(Effbefore + Ei)}{Effbefore} - 1\right)}{100{,}000}$$

Where:

Effbefore = Combustion Efficiency of the furnace before the tune-up

= Actual

EI = Combustion Efficiency Improvement of the furnace tune-up measure[483]

= Actual

For example, for a 100 kBtu furnace in a Des Moines single family house that records an efficiency prior to tune-up of 82% AFUE and has a 1.8% improvement in efficiency after tune-up:

ΔTherms = (100,000 * 991 * (((0.82 + 0.018)/ 0.82) – 1)) /100,000

= 21.8 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[484]

[482] 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.
[483] The percentage improvement in combustion efficiency is deemed a reasonable proxy for the system improvement. If a full thermal efficiency test is performed instead, that should be used.
[484] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

= 0.016525 for Residential Space Heating (other)

For example, for a 100 kBtu furnace in a Des Moines single family house that records an efficiency prior to tune-up of 82% AFUE and has a 1.8% improvement in efficiency after tune-up:

ΔPeakTherms = 21.8 * 0.016525

= 0.3602 therms

Water Impact Descriptions and Calculation

N/A

O&M Cost Adjustment Calculation

While there are likely to be some O&M cost savings due to reduced service calls, increased equipment life, etc., these will only be realized with a regular maintenance schedule, which cannot be assumed for each individual tune-up measure. This benefit is therefore conservatively excluded.

Measure Code: RS-HVC-FTUN-V03-200101

Sunset Date: 1/1/2022

2.4.15 Geothermal Source Heat Pump Tune-Up

NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2019. IT SHOULD NOT BE USED BEYOND THAT DATE BUT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES.

DESCRIPTION

This measure is for the tune-up of a Geothermal Source Heat Pump (GSHP). The tune-up will improve heat pump performance by inspecting, cleaning, and adjusting the heat pump for correct and efficient operation.

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 refers to tune-ups through the HVAC SAVE program and requires certified technicians adhering to all of the requirements of the program. The following are key activities that are provided through an HVAC SAVE program beyond those of a routine annual maintenance[485]:

- Measure pressure drops at return, filter, coil, and supply.
- Determine equipment air flow using OEM blower data or measuring.
- Measure temperature difference (DB, RH or WB) across equipment.
- Determine the OEM's current capacity rating from expanded tables.
- 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.
- Calibrate refrigerant charge.
- Complete final test-out, compare before and after.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a residential heat pump that was installed without Quality Installation and has not already received an HVAC SAVE tune-up.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life of an HVAC SAVE tune-up is the remaining life of the equipment, assume 12 years.

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune-up.

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RE12 – Residential Single Family Water Heat (Electric)

Loadshape RG07 – Residential Water Heat (Gas)

[485] As provided in ANSI approved ACCA 4 specification for Quality Maintenance.

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{SF_{cool}}{EER_{PL}}\right) + FLF_{Cool} * \left(\frac{SF_{cool}}{EER_{FL}}\right)\right)}{1000}\right]$$

$$+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{SF_{heat}}{(COP_{PL} * 3.412)}\right) + FLF_{Heat} * \left(\frac{SF_{heat}}{(COP_{FL} * 3.412)}\right)\right)}{1000}\right]$$

Where:

$EFLH_{Cool}$ = Full load cooling hours

= Dependent on location[486]:

Climate Zone (City based upon)	$EFLH_{cool}$ (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

$Capacity_{Cool}$ = Cooling capacity of Geothermal Source Heat Pump (Btu/hr)

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

PLF_{Cool} = Part load cooling mode operation

= 0.85[487] if variable speed GSHP

= 0 if single/constant speed GSHP

SF_{cool} = Cooling Savings Factor for GSHP tune-ups

=7.5% [488]

FLF_{Cool} = Equivalent full load cooling mode operation factor

= 0.15 if variable speed GSHP

= 1 if single/constant speed GSHP

EER_{PL} = Part load Energy Efficiency Ratio (EER) of efficient GSHP unit

[486] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

[487] Based on Cadmus analysis of the relationship between part- and full-load capacities from building simulations of BEopt (Building Energy Optimization) to generate the energy models. The models were calibrated using Cadmus metered data of 13 high efficiency multi-stage GSHP models functioning in both part- and full-loads.

[488] Calculated based on Cadmus report: Savings percent for a refrigerant charged AC unit, Bin Analysis, Energy Savings Impact of Improving the Installation of Residential Central Air Conditioners, 2005

= Actual installed

EER_{FL} = Full load Energy Efficiency Ratio (EER) of ENERGY STAR GSHP unit

= Actual installed

$EFLH_{Heat}$ = Equivalent Full Load Hours for heating

= Dependent on location[489]:

Climate Zone (City based upon)	$EFLH_{Heat}$ (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	2022	1643	2137
Zone 6 (Mason City)	2874	2335	3037
Average/ unknown (Des Moines)	2272	1846	2401

$Capacity_{Heat}$ = Full load heating capacity of Geothermal Source Heat Pump (Btu/hr)

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

PLF_{Heat} = Part load heating mode operation

= 0.5[490] if variable speed GSHP

= 0 if single/constant speed GSHP

FLF_{Heat} = Full load heating mode operation factor

= 0.5 if variable speed GSHP

= 1 if single/constant speed GSHP

SF_{heat} = Heating Savings Factor for ASHP tune-ups

=2.3% [491]

COP_{PL} = Part load Coefficient of Performance of efficient unit

= Actual Installed

COP_{FL} = Full load Coefficient of Performance of efficient unit

= Actual Installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF)

489 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Heating Degree Day ratios (from NCDC).
490 Based on Cadmus analysis of the relationship between part- and full-load capacities from building simulations of BEopt (Building Energy Optimization) to generate the energy models. The models were calibrated using Cadmus metered data of 13 high efficiency multi-stage GSHP models functioning in both part- and full-loads.
491 Calculated based on Cadmus report: Savings percent for a refrigerant charged AC unit, Bin Analysis, Energy Savings Impact of Improving the Installation of Residential Central Air Conditioners, 2005

> **For example**, for a 3 ton, variable speed GSHP unit with 20 Part Load EER, 18 Full Load EER and 4.4 Part Load COP, 3.4 Full Load COP undergoing a tune-up in an existing, single family home in Des Moines:
>
> ΔkWh = (811 * 36,000 * (0.85 * (7.5%/20) + 0.15 * (7.5%/18))/1,000) + (2,272 * 36,000 * (0.5 * (2.3%/4.4 * 3.412) + 0.5 * (2.3%/3.4 * 3.412))/1,000)
>
> = 255.0 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{SF_{cool}}{EER}\right)}{1000}\right] * CF$$

Where:

EER = Energy Efficiency Ratio (EER) of existing cooling system (kBtuh/kW)

= Actual Installed

CF = Summer system peak Coincidence Factor for cooling

= 72%[492]

> **For example**, for a 3 ton, variable speed GSHP unit with 20 Part Load EER, 18 Full Load EER and 4.4 Part Load COP, 3.4 Full Load COP undergoing a tune-up in an existing, single family home in Des Moines:
>
> ΔkW = (36,000 * (7.5%/18)/1,000) * 72%
>
> = 0.1080 kW

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

O&M COST ADJUSTMENT CALCULATION

While there are likely to be some O&M cost savings due to reduced service calls, increased equipment life, etc., these will only be realized with a regular maintenance schedule, which cannot be assumed for each individual tune-up measure. This benefit is therefore conservatively excluded.

MEASURE CODE: RS-HVC-ASHP-TUN-V02-180101

SUNSET DATE: 1/1/2019

[492] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

2.4.16 Duct Sealing

Description

This measure describes evaluating the savings associated with performing duct sealing using mastic sealant, aerosol, or UL-181 compliant duct sealing tape to the distribution system of homes with either Central Air Conditioner or a ducted heating system. While sealing ducts in conditioned space can help with control and comfort, energy savings are largely limited to sealing ducts in unconditioned space where the heat loss is to outside the thermal envelope. Therefore, for this measure to be applicable, at least 30% of ducts should be within unconditioned space (e.g., attic with floor insulation, vented crawlspace, unheated garages. Basements should be considered conditioned space).

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

1. **Modified Blower Door Subtraction** – this technique is described in detail on p. 44 of the Energy Conservatory Blower Door Manual; see reference file "Energy Conservatory Blower Door Manual.". It involves performing a whole house depressurization test and repeating the test with the ducts excluded.
2. **Duct Blaster Testing** – as described in RESNET Test 803.7: http://www.resnet.us/standards/DRAFT_Chapter_8_July_22.pdf

   This involves using a blower door to pressurize the house to 25 Pascals and pressurizing the duct system using a duct blaster to reach equilibrium with the inside. The air required to reach equilibrium provides a duct leakage estimate.
3. **Deemed Savings per Linear Foot** – this method provides a deemed conservative estimate of savings and should only be used where performance testing described above is not possible.

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

The existing baseline condition is leaky duct work within the unconditioned space in the home.

Deemed Lifetime of Efficient Equipment

The assumed lifetime of this measure is 20 years[493].

Deemed Measure Cost

The actual duct sealing measure cost should be used.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

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

Algorithm

Calculation of Savings

Electric Energy Savings

Methodology 1: Modified Blower Door Subtraction

Claiming Cooling savings from reduction in Air Conditioning Load:

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 below:

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

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

b. Calculate duct leakage reduction, convert to $CFM25_{DL}$[494], and factor in Supply and Return Loss Factors:

[494] 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions.

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

Where:

0.64 = Converts $CFM50_{DL}$ to $CFM25_{DL}$[495]

SLF = Supply Loss Factor[496]

= % leaks sealed located in Supply ducts * 1

Default = 0.5[497]

RLF = Return Loss Factor[498]

= % leaks sealed located in Return ducts * 0.5

Default = 0.25[499]

c. Calculate Energy Savings:

$$\Delta kWh = \Delta kWhcooling + \Delta kWhFan$$

$$\Delta kWhcooling = \frac{\frac{\Delta CFM25_{DL}}{(CapacityCool/12000 * 400)} * EFLHcool * CapacityCool}{1000 * \eta Cool}$$

$$\Delta kWhFan = (\Delta Therms * Fe * 29.3)$$

Where:

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

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

= Actual

12,000 = Converts Btu/H capacity to tons

400 = Conversion of Capacity to CFM (400CFM / ton) [500]

EFLHcool = Equivalent Full Load Cooling Hours

= Dependent on location[501]:

[495] To convert CFM50 to CFM25, multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual).

[496] Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from Energy Conservatory Blower Door Manual.

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

[498] Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than "average" (e.g., pulling return air from a super-heated attic), or can be adjusted downward to represent significantly less energy loss (e.g., pulling return air from a moderate temperature crawl space). More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from Energy Conservatory Blower Door Manual.

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

[500] This conversion is an industry rule of thumb; e.g., see reference file "61-Why 400 CFM per ton."

[501] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations

Climate Zone (City based upon)	EFLHcool (Hours)		
	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

1000 = Converts Btu to kBtu

ηCool = Efficiency in SEER of Air Conditioning equipment

= Actual – If not available, use[502]:

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

ΔTherms = Therm savings as calculated in Natural Gas Savings

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

= 3.14%[503]

29.3 = kWh per therm

were calculated based on relative Cooling Degree Day ratios (from NCDC).

[502] 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.

[503] 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.

For example, for duct sealing in a single family house in Burlington with a 36,000 Btu/H, SEER 11 Central Air Conditioner, 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:

ΔkWh = [((119 / ((36,000/12,000) * 400)) * 918 * 36,000) / (1000 * 11)] + [51.6 * 0.0314 * 29.3]

= 297.9 + 47.5

= 345.4 kWh

Claiming Heating savings for homes with electric heat (Heat Pump):

$$\Delta kWh = \frac{\frac{\Delta CFM25_{DL}}{(CapacityHeat/12000 * 400)} * EFLHelectricheat * CapacityHeat}{\eta Heat * 3412}$$

Where:

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

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

= Actual

EFLHelectricheat = Equivalent Full Load Heating Hours for ASHP

= Dependent on location[504]:

Climate Zone (City based upon)	EFLHelectricheat		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	2022	1643	2137
Zone 6 (Mason City)	2874	2335	3037
Average/ unknown (Des Moines)	2272	1846	2401

[504] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Heating Degree Day ratios (from NCDC).

ηHeat = Efficiency in COP of Heating equipment

= Actual – If not available, use[505]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 and after	8.2	2.40

3412 = Converts Btu to kWh

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

$\Delta kWh_{heating}$ = ((119 / ((36,000/12,000) * 400)) * 2022 * 36,000) / (2.5 * 3412)

= 846.3 kWh

Methodology 2: Duct Blaster Testing

Claiming Cooling savings from reduction in Air Conditioning Load:

$$\Delta kWh = \Delta kWhcooling + \Delta kWhFan$$

$$\Delta kWhcooling = \frac{\frac{Pre\_CFM25 - Post\_CFM25}{CapacityCool/12000 * 400} * EFLHcool * CapacityCool}{1000 * \eta Cool}$$

$$\Delta kWhFan = (\Delta Therms * Fe * 29.3)$$

Where:

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

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

All other variables as provided above

For example, for duct sealing in a single family house in Burlington with a 36,000 Btu/H, SEER 11 Central Air Conditioner, an 80% AFUE, 105,000 Btu/H natural gas furnace, and the following duct blaster test results:

Pre_CFM25 = 220 CFM25

Post_CFM25 = 80 CFM25

ΔkWh = [(((220 - 80) / (36000/12000 * 400)) * 918 * 36000) / (1000 * 11)] + [60.7 * 0.0314 * 29.3]

= 350.5 + 55.8

= 406.3 kWh

Claiming Heating savings for homes with electric heat (Heat Pump):

$$\Delta kWhheating = \frac{\frac{Pre\_CFM25 - Post\_CFM25}{CapacityCool/12000 * 400} * EFLHelectricheat * CapacityHeat}{\eta Heat * 3412}$$

505 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.

Where:

All other variables as provided above

For example, for duct sealing in a 36,000 Btu/H 2.5 COP heat pump heated single family house in Burlington with the duct blaster results described in the example above:

$\Delta kWh_{heating}$ = (((220 - 80) / (36000/12000 * 400)) * 2022 * 36000) / (2.5 * 3412)

= 995.6 kWh

Methodology 3: Deemed Savings[506]

Claiming Cooling savings from reduction in Air Conditioning Load:

$$\Delta kWh = \Delta kWhcooling + \Delta kWhFan$$

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

$$\Delta kWhFan = (\Delta Therms * Fe * 29.3)$$

Where:

CoolSavingsPerUnit = Annual cooling savings per linear foot of duct

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

$Duct_{Length}$ = Total linear feet of duct within the home

= Actual. If unavailable a default of 142ft for single family, 92 ft for Multifamily or 100 ft for manufactured homes can be used[507].

Claiming Heating savings for homes with electric heat (Heat Pump):

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

Where:

HeatSavingsPerUnit = Annual heating savings per linear foot of duct

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

[506] Savings per unit are based upon analysis performed by Cadmus for the 2011 Joint Assessment of Potential. It was based on 10% savings in system efficiency (ENERGY STAR suggests savings potential of up to 20% on its website). This would represent savings from homes with significant duct work outside of the thermal envelope. With no performance testing or verification, a deemed savings value should be very conservative and therefore the values provided in this section represent half of the savings – or 5% improvement.

[507] Based upon Cadmus developed estimate using REMRate assumption of duct surface area to range from 10-15% of conditioned floor area, 6" and 8" duct diameter and square footage based on IUA 2011 Assessment of Potential.

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWhcooling}{EFLHcool} * CF$$

Where:

EFLHcool = Equivalent Full load cooling hours:

= Dependent on location[508]:

Climate Zone (City based upon)	EFLHcool		
	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP[509]

Natural Gas Savings

For homes with Natural Gas Heating:

Methodology 1: Modified Blower Door Subtraction

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

Where:

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

= As calculated in Methodology 1 under electric savings

CapacityHeat = Heating input capacity (Btu/hr)

= Actual

0.0136 = Conversion of Capacity to CFM (0.0136CFM / Btu/hr)[510]

EFLHgasheat = Equivalent Full load heating hours for Furnaces

= Dependent on location[511]:

---

[508] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

[509] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[510] 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, 60% 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 0.0136/Btu.

[511] To calculate the EFLH for an average home as opposed to one with a high efficiency that has been installed using HVAC

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	915	1054	638	896	777	1079
Zone 6 (Mason City)	1302	1496	906	1272	1106	1533
Average/ unknown (Des Moines)	1028	1183	718	1005	874	1212

ηEquipment = Heating Equipment Efficiency

= Actual[512] – If not available, use 87%[513]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[514]

= Actual – If not available use 74%[515]

100,000 = Converts Btu to therms

SAVE, the EFLH developed by TetraTech (see Furnace measure for reference) are adjusted to account for a lower AFUE (85% v 95%) and to derate the AFUE by the factor used for a non-QI furnace. See 'Adjusting EFLH for 'average' home'.xls for more information..

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

513 In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the state. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: (0.60*0.92) + (0.40*0.8) = 0.872.

514 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.

515 Estimated as follows: 0.872 * (1-0.15) = 0.74.

For example, for duct sealing in a house in Burlington 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

= 139 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 * 0.0136)) * 1054 * 105,000 * (0.8/0.74)) / 100,000

= 99.7 therms

Methodology 2: Duct Blaster Testing

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

Where:

All variables as provided above

For example, for duct sealing in a single family house in Burlington with a 36,000 Btu/H, SEER 11 Central Air Conditioner, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following duct blaster test results:

Pre_CFM25 = 220 CFM25

Post_CFM25 = 80 CFM25

ΔTherms = (((220 – 80)/ (105,000 * 0.0136)) * 1054 * 105,000 * (0.8/0.74)) / 100,000

= 117.3 therms

Methodology 3: Deemed Savings[516]

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

[516] Savings per unit are based upon analysis performed by Cadmus for the 2011 Joint Assessment of Potential. It was based on 10% savings in system efficiency (ENERGY STAR suggests savings potential of up to 20% on its website). This would represent savings from homes with significant duct work outside of the thermal envelope. With no performance testing or verification, a deemed savings value should be very conservative and therefore the values provided in this section represent half of the savings – or 5% improvement.

Where:

HeatSavingsPerUnit = Annual heating savings per linear foot of duct

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

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[517]

= 0.016525 for Residential Space Heating (other)

For example, for duct sealing in a single family house in Burlington with a 36,000 Btu/H, SEER 11 Central Air Conditioner, an 80% AFUE, 105,000 Btu/H natural gas furnace, and the following duct blaster test results:

Pre_CFM25 = 220 CFM25

Post_CFM25 = 80 CFM25

ΔPeakTherms = 117.3 * 0.016525

= 1.94 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-DINS-V03-190101

SUNSET DATE: 1/1/2022

[517] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.4.17 Programmable Thermostats

Description

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

Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple programmable thermostats per home does not accrue additional savings.

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

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

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

Definition of Efficient Equipment

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

Definition of Baseline Equipment

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

Deemed Lifetime of Efficient Equipment

The expected measure life of a programmable thermostat is assumed to be 8 years[518].

Deemed Measure Cost

Actual material and labor costs should be used if the implementation method allows. If unknown (e.g. through a retail program), the capital cost for the new installation is assumed to be $70[519].

Loadshape

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

[518] 8 years is based upon ASHRAE Applications (2003), Section 36, Table 3 estimate of 16 years for the equipment life, reduced by 50% to account for persistence issues.

[519] Market prices vary significantly in this category, generally increasing with thermostat capability and sophistication. The basic functions required by this measure's eligibility criteria are available on units readily available in the market for $30. Labor is assumed to be one hour at $40 per hour.

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh^{520} = (\%ElectricHeat * Elec_{Heating_{Consumption}} * \%Controlled * Heating_{Reduction} * Eff_{ISR}) + (\Delta Therms * Fe * 29.3)$$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Controllable Electric Heat (i.e. ducted ASHP or GSHP)	100%
Natural Gas	0%
Unknown	6%[521]

Elec_Heating_ Consumption

= Estimate of annual household heating consumption for electrically heated homes[522]. If location and heating type is unknown, assume 10,599 kWh[523]

		Elec_Heating_ Consumption (kWH) by Climate Zone (City based upon)		
Heating System[524]	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Air-Source Heat Pump	Manufactured	9,031	12,838	10,148
	Multifamily	5,576	7,927	6,266
	Single-family	10,396	14,778	11,682
Ground-Source Heat Pump	Manufactured	5,247	7,459	5,896
	Multifamily	3,234	4,597	3,634
	Single-family	6,029	8,571	6,775

%Controlled = Assumed percentage of household heating consumption that is controlled by the thermostat

= If single zone, assume 100%

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

521 Average (default) value of 6% electric ducted heat pump space heating from 2009 Residential Energy Consumption Survey for Iowa (note advanced thermostats are unlikely to be applied to resistance heating or ductless heat pumps). 2015 Residential Energy Consumption Data was not used as it does not have the geographical specificity that is provided in 2009. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

522 Based on Cadmus modeling performed for the 2011 Joint Assessment.

523 Assumes Air Source Heat Pump consumption values and 80% Single Family and 20% Multi Family, based on 2009 Residential Energy Consumption Survey for Iowa, see "HC2.9 Structural and Geographic in Midwest Region.xls". 2015 Residential Energy Consumption Data was not used as it does not have the geographical specificity that is provided in 2009.

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

= If single zone thermostat in multi zone home, assume 1 / # zones

= If multi zone thermostat, assume 100%

= If unknown, assume 93%[525]

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

= 6.2%[526]

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%[527]

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%[528]

29.3 = kWh per therm

Based on defaults provided above[529]:

			ΔkWh by Climate Zone (city based upon)					
			Direct Install[530]			Other Programs		
Heating Fuel	Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Electrically Heated Home	Air-Source Heat Pump	Manufactured	559.9	795.9	629.2	291.6	414.5	327.7
		Multifamily	345.7	491.5	388.5	180.1	256.0	202.3
		Single-family	644.6	916.3	724.3	335.7	477.2	377.2
	Ground-Source Heat Pump	Manufactured	325.3	462.4	365.6	169.4	240.8	190.4
		Multifamily	200.5	285.0	225.3	104.4	148.4	117.3
		Single-family	373.8	531.4	420.1	194.7	276.7	218.8

525 RECS Table HC6.9 Space Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009, indicates that 14% of homes have two or more thermostats in the region. If it is unknown the total heat consumption per thermostat is reduced by 7%, assuming that the 14% are controlling 50% of the homes total consumption. 2015 Residential Energy Consumption Data was not used as it does not have the geographical specificity that is provided in 2009.

526 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; RLW Analytics, 2007 "Validating the Impact of Programmable Thermostats", 2007. To the extent that the treatment group is representative of the program participants for IA, 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.

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

528 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.

529 See "Programmable Thermostat Savings_03252019.xls" for calculation detail.

530 Assumes single zone. If not – adjust accordingly.

			ΔkWh by Climate Zone (city based upon)					
			Direct Install[530]			Other Programs		
Heating Fuel	Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Gas Heated Home	Furnace	Manufactured	26.7	37.9	29.9	13.9	19.7	15.6
		Multifamily	17.7	25.1	19.9	9.2	13.1	10.3
		Single-family	30.6	43.5	34.4	15.9	22.7	17.9
	Boiler	Manufactured	34.1	48.5	38.3	17.8	25.3	20.0
		Multifamily	27.5	39.0	30.9	14.3	20.3	16.1
		Single-family	37.9	53.9	42.6	19.7	28.1	22.2
Unknown Heat and Location			n/a	n/a	75.0	n/a	n/a	41.1

Summer Coincident Peak Demand Savings

N/A due to no savings from cooling during the summer peak period.

Natural Gas Energy Savings

$$\Delta Therms = \%FossilHeat * Gas\_Heating\_Consumption * \%Controlled * Heating\_Reduction * Eff\_ISR$$

Where:

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

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	94%[531]

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes[532]. If location is unknown, assume 578therms[533]

		Gas_Heating_Consumption (Therms) by Climate Zone (City based upon)		
Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Heat Central Furnace	Manufactured	467	664	525
	Multifamily	310	440	348
	Single-family	537	763	603
Heat Central	Manufactured	598	850	672

[531] Average (default) value of 83% gas space heating from 2009 Residential Energy Consumption Survey for Iowa. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

[532] Based on Cadmus modeling performed for the 2011 Joint Assessment.

[533] Assumption that 83% of gas heated homes have furnaces and 17% have boilers, based on 2009 Residential Energy Consumption Survey for Iowa, see "HC6.9 Space Heating in Midwest Region.xls". Assume 80% Single Family and 20% Multifamily, based on 2009 Residential Energy Consumption Survey for Iowa, see "HC2.9 Structural and Geographic in Midwest Region.xls".

Heating System	Building Type	Gas_Heating_Consumption (Therms) by Climate Zone (City based upon)		
		Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Boiler	Multifamily	481	684	541
	Single-family	665	945	747

Based on defaults provided above[534]:

Heating System	Building Type	ΔTherms by Climate Zone (city based upon)					
		Direct Install[535]			Other Programs		
		Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Heat Central Furnace	Manufactured	29.0	41.2	32.6	15.1	21.4	17.0
	Multifamily	19.2	27.3	21.6	10.0	14.2	11.2
	Single-family	33.3	47.3	37.4	17.3	24.6	19.5
Heat Central Boiler	Manufactured	37.1	52.7	41.7	19.3	27.4	21.7
	Multifamily	29.9	42.4	33.5	15.5	22.1	17.5
	Single-family	41.2	58.6	46.3	21.5	30.5	24.1
Unknown Heat and Location		n/a	n/a	36.9	n/a	n/a	19.2

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[536]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

Based on defaults provided above:

Heating System	Building Type	ΔTherms by Climate Zone (city based upon)					
		Direct Install			Other Programs		
		Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Heat Central Furnace	Manufactured	0.4787	0.6805	0.5379	0.2493	0.3544	0.2801
	Multifamily	0.3173	0.4510	0.3565	0.1653	0.2349	0.1857
	Single-family	0.5498	0.7815	0.6178	0.2863	0.4070	0.3218

534 See "Programmable Thermostat Savings.xls" for calculation detail.
535 Assumes single zone. If not – adjust accordingly.
536 Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

		ΔTherms by Climate Zone (city based upon)					
		Direct Install			Other Programs		
Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Heat Central Boiler	Manufactured	0.5331	0.7578	0.5990	0.2776	0.3947	0.3120
	Multifamily	0.4292	0.6101	0.4823	0.2235	0.3177	0.2512
	Single-family	0.5926	0.8424	0.6659	0.3086	0.4387	0.3468
Unknown Heat and Location[537]		n/a	n/a	0.5953	n/a	n/a	0.3100

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-PROG-V03-200101

SUNSET DATE: 1/1/2023

[537] Assumes 83% furnace v 17% boiler as per 'Table HC6.9 Space Heating in U.S. Homes in Midwest Region, Divisions and States, 2009'. See "Programmable Thermostat Savings.xls" for calculation detail.

2.4.18 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 within conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[538] 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. [539] 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 an ENERGY STAR qualified Advanced Thermostat, with the default enabled capability—or the capability to automatically—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[540] 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,[541] or an assumed mix of these two

[538] 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.

[539] 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'.

[540] 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.

[541] If the actual thermostat is a programmable and it is found to be used in override mode or otherwise effectively being

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[542].

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[543] based upon equipment life only.[544]

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, BYOT, or other program types, actual costs[545] should be used if available, along with a baseline equipment cost of $50. If actual costs are unknown, then the average incremental cost for the new installation measure is assumed to be $125[546].

Loadshape

ΔkWh	→ RE08 – Residential Single Family Heat Pump
$\Delta kWh_{heating}$	→ RE06 – Residential Single Family Central Heat
	→ RE01 – Residential Multifamily Central Heat
$\Delta kWh_{cooling}$	→ RE07 – Residential Single Family Cooling
	→ RE02 – Residential Multifamily Cooling
$\Delta Therms$	→ RG02 – Residential Boiler
	→ RG04 – Residential Other Heating

Algorithm

Calculation of Savings

Electric Energy Savings

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

$$\Delta kWh_{heat} = \%ElectricHeat * Elec\_Heating\_Consumption * \%Controlled * Heating\_Reduction * HF * Eff\_ISR + (\Delta Therms * Fe * 29.3)$$

$$\Delta kWh_{cool} = \%AC * ((EFLH_{cool} * Capacity_{cool} * 1/SEERbase)/1000) * \%Controlled * Cooling\_Reduction * Eff\_ISR$$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

operated like a manual thermostat, then the baseline may be considered to be a manual thermostat

[542] Value for blend of baseline thermostats comes from an IL Potential Study conducted by ComEd in 2013

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

[544] 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.

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

[546] ENERGY STAR models are currently being offered in the $150-$200 range. The assumed incremental cost is based on the middle of this range ($175) 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.

Heating fuel	%ElectricHeat
Controllable Electric Heat (i.e., ducted ASHP, GSHP or forced air electric furnace)	100%
Natural Gas	0%
Unknown	6%[547]

Elec_Heating_Consumption

= Estimate of annual household heating consumption for electrically heated single-family homes[548]. If location and heating type is unknown, assume 11,407 kWh[549].

		Elec_Heating_ Consumption (kWH) by Climate Zone (City based upon)		
Heating System[550]	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Air-Source Heat Pump	Manufactured	9,031	12,838	10,148
	Multifamily	5,576	7,927	6,266
	Single-family	10,396	14,778	11,682
Ground-Source Heat Pump	Manufactured	5,247	7,459	5,896
	Multifamily	3,234	4,597	3,634
	Single-family	6,029	8,571	6,775
Forced Air Electric Furnace	Manufactured	11,325	16,098	12,725
	Multifamily	7,619	10,830	8,561
	Single-family	12,454	17,703	13,994

%Controlled = Assumed percentage of household heating consumption that is controlled by the thermostat

= If single zone, assume 100%

= If single zone thermostat in multi zone home, assume 1 / # zones

= If multi zone thermostat, assume 100%

= If unknown, assume 93%[551]

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

547 Average (default) value of 6% electric ducted heat pump space heating from 2009 Residential Energy Consumption Survey for Iowa (note advanced thermostats are unlikely to be applied to resistance heating or ductless heat pumps). If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

548 Based on Cadmus modeling performed for the 2011 Joint Assessment.

549 Assumes 65% Air Source Heat Pump consumption value, 35% Forced Air Electric Furnace (data provided by Cedar Falls Utility program) and 80% Single Family and 20% Multi Family (based on 2009 Residential Energy Consumption Survey for Iowa), see "HC2.9 Structural and Geographic in Midwest Region.xls".

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

551 RECS Table HC6.9 Space Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009, indicates that 14% of homes have two or more thermostats in the region. If it is unknown the total heat consumption per thermostat is reduced by 7%, assuming that the 14% are controlling 50% of the homes total consumption.

= If programs are evaluated during program deployment then custom savings assumptions should be applied. Otherwise use:

Existing Thermostat Type	Heating_Reduction[552]
Manual	8.8%
Programmable	5.6%
Unknown (Blended)	6.8%

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

Household Type	HF
Single-Family	100%
Multifamily	65%[553]
Actual	Custom[554]

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication

= If programs are evaluated during program deployment then custom ISR assumptions should be applied. If in service rate is captured within the savings percentage, ISR should be 100%. If using default savings:

Program Delivery	Eff_ISR
Direct Install	100%
Other	100%[555]

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%[556]

29.3 = kWh per therm

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

Thermostat control of air conditioning?	%AC
Yes	100%

[552] These values represent adjusted baseline savings values for different existing thermostats as presented in Navigant's IL TRM Workpaper on Impact Analysis from Preliminary Gas savings findings (page 28). The unknown assumption is calculated by multiplying the savings for manual and programmable thermostats by their respective share of baseline, based upon results from the Dunsky and Opinion Dynamics 2017 Baseline Study.

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

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

[555] 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.

[556] 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
No	0%
Unknown	Actual population data, or 88%[557]

$EFLH_{cool}$ = 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 (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	548	918	504	736	508	865
Zone 6 (Mason City)	279	468	257	375	259	441
Average/ unknown (Des Moines)	484	811	445	650	449	764

$Capacity_{cool}$ = Cooling Capacity of new equipment in Btu/hr (note 1 ton = 12,000Btu/hr)

= Actual installed – If actual size unknown, assume 36,000

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

= 13[558]

1/1000 = kBtu per Btu

Cooling_Reduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat

= If programs are evaluated during program deployment then custom savings assumptions should be applied. Otherwise use:

= 8.0%[559]

For example, an advanced thermostat replacing a programmable thermostat directly installed in a single zone air source heat pump heated, single-family home in Mason City with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

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

$= ((1 * 14,778 * 5.6\% * 100\% * 100\%) + (0 * 3.14\% * 29.3)) + (100\% * ((468 * 36,000 * (1/13))/1000) * 8\% * 100\%)$

$= 828 + 104$

$= 932$ kWh

557 88% of homes have central cooling (based on Dunsky and Opinion Dynamics Baseline Study results).

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

559 Note: This factor represents estimated savings as a percentage of cooling consumption. When reviewing against factors from other evaluations, it is important to understand whether savings percentages are applied against cooling, cooling and heating fan or total annual household kWh. 8% is consistent with the Illinois TRM assumption pending an upcoming statewide advanced thermostat evaluation utilizing participant AMI data. Further evaluation and regular review of this key assumption is encouraged.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \%AC * (\%Controlled * Cooling\_Reduction * Capacity_{cool} * (1/EER))/1000 * Eff\_ISR * CF$$

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:

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

If SEER or EER rating unavailable use[560]:

Cooling System	EER561
Air Source Heat Pump	8.55
Central AC	8.15

CF = Summer System Peak Coincidence Factor for Cooling

= 34%[562]

> **For example**, an advanced thermostat replacing a programmable thermostat directly installed in a single zoned air source heat pump heated, single-family home in Mason City with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:
>
> ΔkW = (8% * 36,000 * (1/8.15))/1000 * 100% * 34%
>
> = 0.1201 kW

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \%FossilHeat * Gas\_Heating\_Consumption * \%Controlled * Heating\_Reduction * HF * Eff\_ISR$$

Where:

%FossilHeat

= Percentage of heating savings assumed to be Natural Gas

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	94%[563]

Gas_Heating_Consumption

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

561 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, Illinois PY3-PY4 program data.

562 In the absence of conclusive results from empirical studies on peak savings, we recommend 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.

563 Average (default) value of 94% gas space heating from 2009 Residential Energy Consumption Survey for Iowa. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume 578 therms[564].

Heating System	Building Type	Gas_Heating_Consumption (Therms) by Climate Zone (City based upon) Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown (Des Moines)
Heat Central Furnace	Manufactured	467	664	525
	Multifamily	310	440	348
	Single-family	537	763	603
Heat Central Boiler	Manufactured	598	850	672
	Multifamily	481	684	541
	Single-family	665	945	747

Other variables as provided above

For example, an advanced thermostat replacing a programmable thermostat directly-installed in a single zoned gas heated furnace single-family home in Des Moines:

ΔTherms = 1.0 * 603 * 5.6% * 100% * 100%

= 33.77 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[565]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, an advanced thermostat replacing a programmable thermostat directly-installed in a single zoned gas heated furnace single-family home in Des Moines:

ΔPeak Therms = 33.77 * 0.016525

= 0.558 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[564] Assumption that 83% of gas heated homes have furnaces and 17% have boilers, based on 2009 Residential Energy Consumption Survey for Iowa, see “HC6.9 Space Heating in Midwest Region.xls”. Assume 80% Single Family and 20% Multifamily, based on 2009 Residential Energy Consumption Survey for Iowa, see “HC2.9 Structural and Geographic in Midwest Region.xls”.

[565] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

MEASURE CODE: RS-HVC-ADTH-V04-200101

SUNSET DATE: 1/1/2021

2.4.19 Duct Insulation

Description

Energy and demand saving are realized through reductions in the home cooling and heating loads by insulating ductwork in unconditioned areas (e.g., attic with floor insulation, vented crawlspace, unheated garages. Basements should be considered conditioned space). If sealing of ducts is unknown, the sealed efficiency should be used.

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 ductwork in unconditioned areas that has been insulated.

Definition of Baseline Equipment

The baseline condition is the existing uninsulated or poorly insulated ductwork in unconditioned areas.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[566]

Deemed Measure Cost

The actual duct insulation measure cost should be used.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Algorithm

Calculation of Energy Savings

Savings should only be claimed for ductwork that exists on the exterior of the home or in uninsulated spaces.

Electric Energy Savings

Electric energy savings is calculated as the sum of energy saved when cooling the home and energy saved when heating the building

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1{,}000 * \eta_{cooling})}$$

Where:

566 Consistent with duct insulation measure life specified in the MidAmerican Energy Company Joint Assessment, February 2013.

$R_{existing}$ = Duct heat loss coefficient of existing duct [(hr-^{o}F-ft^{2})/Btu]

= Estimate of actual with minimum of 1.0 for uninsulated duct[567]

R_{new} = Duct heat loss coefficient with new insulation [(hr-^{o}F-ft^{2})/Btu]

= Actual

Area = Area of the duct surface exposed to the unconditioned space that has been insulated [ft^{2}]. (e.g. for circular duct – Calculate the circumference of the duct (= π * diameter) multiplied by length (ft))

$EFLH_{cooling}$ = Equivalent Full Load Cooling Hours

= Dependent on location[568]:

Climate Zone (City based upon)	$EFLH_{cooling}$		
	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/Unknown (Des Moines)	811	650	764

$\Delta T_{AVG,cooling}$ = Average temperature difference [^{o}F] during cooling season between outdoor air temperature and assumed 60^{o}F duct supply air temperature[569]

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][570]	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	20.4
Zone 6 (Mason City)	78.6	18.6
Average/Unknown (Des Moines)	75.2	15.2

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)

= Actual – If not available, use[571]:

Equipment Type	Age of Equipment	SEER Estimate of Sealed Duct	SEER Estimate of Unsealed Duct (SEER*0.85)
Central AC	Before 2006	10	8.5
	After 2006	13	11.05
Heat Pump	Before 2006	10	8.5

567 Based upon findings in ACEEE study of internal film resistance: L. Palmiter and E Kruse, Ecotope Inc, "True R-Values of Round Residential Ductwork".
568 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).
569 Leaving coil air temperatures are typically about 55^{o}F. 60^{o}F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.
570 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.
571 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.

Equipment Type	Age of Equipment	SEER Estimate of Sealed Duct	SEER Estimate of Unsealed Duct (SEER*0.85)
	2006-2014	13	11.05
	2015 on	14	11.9

For example, a single family house in Burlington with Central Air SEER = 13 and 10 ft. of uninsulated standard 6-inch round sealed duct in an unconditioned space.

$\Delta kWh_{cooling}$ = ((1/1.0 – 1/(1.0 + 6)) * (π *0.5 * 10) * 918 * 20.4) / (1000 * 13)

= 19.4 kWh

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

$$\Delta \text{kWh}_{\text{heating}} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 \ * \ \eta_{heating})}$$

Where:

$EFLH_{heating}$ = Equivalent Full Load Heating Hours for ASHP

= Dependent on location[572]:

Climate Zone (City based upon)	$EFLH_{heating}$		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	2022	1643	2137
Zone 6 (Mason City)	2874	2335	3037
Average/Unknown (Des Moines)	2272	1846	2401

$\Delta T_{AVG,heating}$ = Average temperature difference [^{o}F] during heating season between outdoor air temperature and assumed 115^{o}F duct supply temperature[573]

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][574]	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	75.4
Zone 6 (Mason City)	35.9	79.1
Average/Unknown (Des Moines)	30.1	84.9

3,142 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system

572 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Heating Degree Day ratios (from NCDC).

573 Forced air supply temperatures are typically 130^{o}F. 115^{o}F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

574 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

= Actual – If not available, use[575]:

System Type	Age of Equipment	HSPF Estimate	nHeat (Effective COP Estimate) of Sealed Ducts (HSPF/3.412)	ηHeat (Effective COP Estimate) of Unsealed Ducts (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.99	1.69
	2006 – 2014	7.7	2.26	1.92
	2015 on	8.2	2.40	2.04

For example, a single family house in Burlington with a Heat Pump COP = 1.92 and 10 ft. of uninsulated standard 6-inch round sealed duct in an unconditioned space.

$\Delta kWh_{heating}$ = ((1/1.0 – 1/(1.0 + 6)) * (π * 0.5 * 10) * 2022 * 75.4) / (3412 * 2.0)

= 300.8 kWh

If the home is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$\Delta kWh_{heating}$ = ΔTherms * Fe * 29.3

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[576]

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWhcooling}{EFLHcooling} * CF$$

Where:

$EFLH_{cooling}$ = Equivalent Full Load Cooling Hours

= Dependent on location[577]:

Climate Zone (City based upon)	$EFLH_{cooling}$		
	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441

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

576 F_e is not one of the AHRI certified ratings provided for 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% for residential units. 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. Assumed to be consistent with C&I applications.

577 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

Climate Zone (City based upon)	$EFLH_{cooling}$		
	Single Family	Multifamily	Manufactured
Average/Unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP[578]

For example, using the above for a single family house in Burlington with Central Air SEER = 13 and 10 ft. of uninsulated standard 6-inch round sealed duct in an unconditioned space.

ΔkW = 19.4 / 918 * 0.68

= 0.0144 kW

Natural Gas Savings

If homes with a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLH_{gasheat} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

Where:

$R_{existing}$ = Duct heat loss coefficient with existing insulation [(hr-°F-ft^2)/Btu]

R_{new} = Duct heat loss coefficient with new insulation [(hr-°F-ft^2)/Btu]

Area = Area of the duct surface exposed to the unconditioned space that has been insulated [ft^2].

$EFLH_{gasheat}$ = Equivalent Full load heating hours for Furnaces (see above)

= Dependent on location[579]:

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	915	1054	638	896	777	1079
Zone 6 (Mason City)	1302	1496	906	1272	1106	1533
Average/ unknown (Des Moines)	1028	1183	718	1005	874	1212

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season (see above)

[578] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[579] To calculate the EFLH for an average home as opposed to one with a high efficiency that has been installed using HVAC SAVE, the EFLH developed by TetraTech (see Furnace measure for reference) are adjusted to account for a lower AFUE (85% v 95%) and to derate the AFUE by the factor used for a non-QI furnace. See 'Adjusting EFLH for 'average' home'.xls for more information.

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of gas heating system

= Actual[580] – If not available, use 87%[581] for sealed ducts or 74%[582] for unsealed ducts

For example, a single family house in Burlington with a gas heating system COP = 0.87 and 10 ft. of uninsulated standard 6-inch round sealed ducts in an unconditioned space.

ΔTherms = ((1/1.0 – 1/(1.0 + 6)) * (π * 0.5 * 10) * 1054 * 75.4) / (100,000 * 0.87)

= 12.3 Therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[583]

= 0.016525 for Residential Space Heating (other)

For example, using the above, a single family house in Burlington with a gas heating system COP = 0.87 and 10 ft. of uninsulated standard 6-inch round sealed ducts in an unconditioned space.

ΔPeakTherms = 12.3 * 0.016525

= 0.203 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-DUCT-V03-200101

SUNSET DATE: 1/1/2022

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

[581] In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the state. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: (0.60*0.92) + (0.40*0.8) = 0.872.

[582] An 85% distribution efficiency is then applied to account for duct losses for furnaces.

[583] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.4.20 Advanced Thermostat Optimization Services

Description

This measure provides the characterization of additional savings to the Advanced Thermostat measure which are achieved for participants that enroll in a program that provides additional optimization of the Advanced Thermostat control strategy. This software add on deploys a set point altering algorithm to generate additional heating and cooling savings than would be realized from just the advanced thermostat alone.

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 case is a participant that has enrolled on the Advanced Thermostat Optimization Service program.

Definition of Baseline Equipment

The baseline is an advanced thermostat that has not enrolled on the Advanced Thermostat Optimization Service program.

Deemed Lifetime of Efficient Equipment

The expected measure life for savings associated with the program is 1 year.[584]

Deemed Measure Cost

The measure cost is the cost to enroll in the program and should be based on actual costs. For planning purposes a cost of $6.00 per participant for a single year can be used based on proposals provided for other utility programs.

Loadshape

ΔkWh	→ RE08 – Residential Single Family Heat Pump
$\Delta kWh_{heating}$	→ RE06 – Residential Single Family Central Heat
	→ RE01 – Residential Multifamily Central Heat
$\Delta kWh_{cooling}$	→ RE07 – Residential Single Family Cooling
	→ RE02 – Residential Multifamily Cooling
ΔTherms	→ RG02 – Residential Boiler
	→ RG04 – Residential Other Heating

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = \Delta kWh_{HeatingOptimized} + kWh_{CoolingOptimized}$$

$$\Delta kWh_{HeatingOptimized} = NewHeatingConsumption * Heating_{OptimizedReduction}$$

$$\Delta kWh_{CoolingOptimized} = NewCoolingConsumption * Cooling_{OptimizedReduction}$$

Where:

NewCoolingConsumption = New cooling consumption – i.e. calculation of consumption after subtracting

[584] The annual savings characterized are achieved during any year the participant is enrolled.

the base level savings from the Advanced Thermostat measure.

$Cooling_{OptimizedReduction}$ = Assumed percentage reduction in household cooling energy consumption due to Nest Seasonal Savings.

= 2.2%[585]

NewHeatingConsumption = New heating consumption – i.e. calculation of consumption after subtracting the base level savings from the Advanced Thermostat measure

$Heating_{OptimizedReduction}$ = Assumed percentage reduction in household heating energy consumption due to Nest Seasonal Savings.

= 3.5%[586]

For example, an advanced thermostat enrolled in the Advanced Thermostat Optimization program in a single zone air source heat pump heated, single-family home in Mason City with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

ΔkWH = $\Delta kWh_{HeatingOptimized} + \Delta kWh_{CoolingOptimized}$

= (14,778 – 828) * 3.5% + (1296 - 104) * 2.2%

= 488.25 + 26.22

= 514 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh_{CoolingSeasonal}}{EFLH_{Cool}}$$

Where:

$EFLH_{Cool}$ = Equivalent Full Load Hours of air conditioning

= Dependent on loction[587]

Climate Zone (City based upon)	$EFLH_{cool}$ (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	548	918	504	736	508	865
Zone 6 (Mason City)	279	468	257	375	259	441
Average/ unknown (Des Moines)	484	811	445	650	449	764

585 Reduction of 2.2% based on evaluation of DCSEU program: NMR, March 2019, “Nest Seasonal Savings Evaluation”.

586 3.5% based on findings from a deployment with over 20,000 units in Massachusetts (Page 2, Request for Approval of MCE Seasonal Savings Pilot Program, MCE, August 18, 2016. MCE-AL-17-E-Seasonal-Savings-Pilot.pdf). The savings determined through this evaluation represents the average savings from all participants, including those that pull out or override the program.

587 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from National Climatic Data Center, NCDC).

For example, an advanced thermostat enrolled in the Seasonal Savings program in a single zoned air source heat pump heated, single-family home in Mason City with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

ΔkW = 26.22 / 918

= 0.0286 kW

Natural Gas Energy Savings

$$\Delta Therms = NewGastHeatingConsumption * Heating_{OptimizedReduction}$$

Where:

NewGasHeatingConsumption = New heating consumption – i.e. calculation of consumption after subtracting the base level savings from the Advanced Thermostat measure

Other variables as provided above

For example, an advanced thermostat enrolled in the Advanced Thermostat Optimization program in a single zoned gas heated furnace single-family home in Des Moines:

ΔTherms = (603-33.77) * 3.5%

= 19.92 Therms

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[588]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, an advanced thermostat enrolled in the Advanced Thermostat Optimization program in a single zoned gas heated furnace single-family home in Des Moines:

ΔPeakTherms = 19.92 * 0.016525

= 0.3292 Therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

[588] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

MEASURE CODE: RS-HVC-AOPT-V02-200101

SUNSET DATE: 1/1/2021

2.5 Lighting

2.5.1 Compact Fluorescent Lamp – Standard

NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2017. IT SHOULD NOT BE USED BEYOND THAT DATE BUT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES.

DESCRIPTION

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

This characterization provides assumptions for when the CFL is installed in a known location (i.e., residential and in-unit interior or exterior) or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program or efficiency kit), an unknown residential location assumption is provided. For upstream programs, utilities should develop an assumption of the Residential v Nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard. Furthermore, the Technical Advisory Committee approved assuming a blended baseline condition of EISA qualified incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

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.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a standard general service ENERGY STAR qualified compact fluorescent lamp based upon the v1.1 ENERGY STAR specification for lamps (https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf. Note a new ENERGY STAR specification v2.0 will become effective on 1/2/2017 (https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf).

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 70% EISA qualified halogen or incandescent and 20% CFL and 5% LED[589].

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

For Residential, Multifamily In-unit bulbs, and Unknown: The expected lifetime of a CFL is assumed to be 5.2 years[590].

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[589] As proposed and discussed by Iowa TRM Oversight Committee and Technical Advisory Committee.

[590] Jump et al. 2008: "Welcome to the Dark Side: The Effect of Switching on CFL Measure Life" indicates that the “observed life”

To account for the backstop provision of the EISA 2007 legislation, for bulbs installed in 2015 this would be reduced to 5 years, and then for every subsequent year should be reduced by one year[591].

Exterior bulbs: The expected measure life is 4.0 years[592] for bulbs up to 2016. For bulbs installed in 2017 this would be reduced to 3 years, etc.

DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for all bulbs under 2,000 lumens is $1.03[593] (baseline cost of $2.17[594] and efficient cost of $3.20).

For bulbs over 2,000 lumens, the assumed incremental capital cost is $2.76[595] (baseline cost of $3.44[596] and efficient cost of $6.20).

For the Direct Install measure, actual program delivery costs should be used if available. If not, the full cost of $3.20[597] per bulb <2000 lumens or $6.20 per bulb ≥ 2000 lumens should be used, plus $10 labor[598], for a total measure cost of $13.20 per <2,000 lumen bulb and $16.20 per ≥ 2,000 lumen bulb.

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

LOADSHAPE

Loadshape RE09 – Residential Indoor Lighting

Loadshape RE10 – Residential Outdoor Lighting

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$ = Based on lumens of CFL bulb installed and includes blend of incandescent/halogen[599],

of CFLs with an average rated life of 8000 hours (8000 hours is the average rated life of ENERGY STAR bulbs (http://www.energystar.gov/index.cfm?c=cfls.pr_crit_cfls) is 5.2 years.

591 Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point forward.

592 Based on using 10,000 hour rated life, minimum ENERGY STAR v1.1 requirement. 10,000/2475 = 4.0 years

593 Incandescent/halogen and CFL assumptions based on incremental costs for 60W equivalent (dominant bulb) from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

594 Based on 70% Incandescent ($1.40), 25% CFL ($3.20) and 5% LED ($7.87). LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

595 Based on high brightness lamps from“2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

596 Based on 70% Incandescent ($1.60), 25% CFL ($6.20) and 5% LED ($15.39)

597 Based on 15W CFL, “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

598 Assumption based on 15 minutes (including portion of travel time) and $40 per hour.

599 Incandescent/Halogen wattage is based upon the post first phase of EISA wattage and wattage bins consistent with ENERGY STAR, v1.1; http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

CFL and LED by weightings provided in table below[600]. Note that when an IA net-to-gross (NTG) factor is determined for this measure, this blended baseline should be replaced with the Incandescent/Halogen baseline only.

$Watts_{EE}$ = Actual wattage of CFL purchased / installed – If unknown, assume the following defaults[601]:

Lower Lumen Range	Upper Lumen Range	Inc/Halogen	$Watts_{EE}$ CFL	LED	$Watts_{Base}$	Delta Watts
		70%	25%	5%		
250	309	25	5.1	4.0	19.0	13.9
310	749	29	9.4	6.7	23.0	13.6
750	1,049	43	13.4	10.1	33.9	20.6
1,050	1,489	53	18.9	12.8	42.5	23.5
1,490	2,600	72	24.8	17.4	57.5	32.7
2,601	3,000	150	41.1	43.1	117.4	76.3
3,001	3,999	200	53.8	53.8	156.2	102.3
4,000	6,000	300	65.0	76.9	230.1	165.1

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

Program		# of bulbs	Discounted In Service Rate (ISR)[602]
Retail (Time of Sale)[603]			92%
Direct Install[604]			97%
Efficiency Kits	School Kits[605]	1	57%
		2	48%
		3	42%
		Unknown[606]	49%
	EnergyWise (Low Income)[607]	1	79%
		2	74%
		Unknown[608]	76.5%

[600] Weightings were determined through discussions with the Technical Advisory Committee. These are based upon review of Itron socket saturation and inventory data, in addition to review of multiple other data sources on the lighting market in other jurisdictions.
[601] $Watts_{EE}$ defaults are based upon the average available ENERGY STAR product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR product currently available, $Watts_{EE}$ is based upon the ENERGY STAR minimum luminous efficacy (55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts) for the mid-point of the lumen range. See calculation at “cerified-light-bulbs-2015-06-18.xlsx”. These assumptions should be reviewed regularly to ensure they represent the available product.
[602] All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%); see “Res Lighting ISR calculation.xlsx” for more information.
[603] In service rate for Retail CFLs is based upon recommendation in the Uniform Methods Project to use data from the Navigant Consulting and Apex Analytics (2013) study.
[604] Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys; http://www.ilsag.info/evaluation-documents.html
[605] Based on results provided in “School-based interim process memo_Final_100215.doc”.
[606] Average of above.
[607] Based on Cadmus, “Final Report: Iowa 2015 Energy Wise Program”, January 29, 2016, p16.
[608] Average of above.

Hours = Average hours of use per year

Installation Location	Hours
Residential Interior and in-unit Multifamily	894[609]
Exterior	2,475 [610]
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	973[611]

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section)

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

If unknown assume 0.94[612]

Where:

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

= 53%[613] for interior or unknown location

= 0% for exterior or unheated location

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

= Actual - If not available, use[614]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 and after	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.38[615]

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%

609 Average of four Midwest metering studies: 2011 Ameren Missouri Lighting and Appliance Evaluation – PY 2; 2012 Consumers Energy - Technical Memo; 2012 DTE - Technical Memo; and PY5/PY6 ComEd, Illinois Residential Lighting Program evaluation.
610 Based on secondary research conducted as part of the Illinois PY5/PY6 ComEd Residential Lighting Program evaluation.
611 Assumes 5% exterior lighting, based on Illinois PY5/PY6 ComEd Residential Lighting Program evaluation.
612 Calculated using defaults: 1-((0.53/1.38) * 0.15) = 0.94
613 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington.
614 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 and 2015 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.
615 Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on assumption 50% are units from before 2006 and 50% 2006-2014.

Heating fuel	%ElecHeat
Fossil Fuel	0%
Unknown	15%[616]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[617]
Building without cooling or exterior	1.0
Unknown	1.08[618]

For example, for a 900 lumen 17W standard CFL in an unknown location:

ΔkWh = ((33.9 - 17) / 1000) * 0.92 * 973 * (0.94 + (1.08 – 1))

= 15.4 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * WHFdCool * CF$$

Where:

WHFdCool = Waste Heat Factor for demand to account for cooling savings from efficient lighting

Bulb Location	WHFdCool
Building with cooling	1.22[619]
Building without cooling or exterior	1.0
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1.14[620]

CF = Summer peak Coincidence Factor for measure

Bulb Location	CF
Residential Interior and in-unit Multifamily [621]	13.1%

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

[617] The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). Based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * $SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

[618] The value is estimated at 1.09 (calculated as 1 + (0.64*(0.34 / 2.8)). Based on assumption that 64% of homes have central cooling (based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region.xls").

[619] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour) consistent with the lighting peak hours.

[620] The value is estimated at 1.14 (calculated as 1 + (0.64 * 0.61 / 2.8)).

[621] Based on analysis of loadshape data provided by Cadmus.

Bulb Location	CF
Exterior [622]	1.8%
Unknown (e.g., Retail, Upstream and Efficiency Kits)[623]	12.5%

Other factors as defined above

For example, for a 900 lumen 17W standard CFL in an unknown location:

ΔkW = ((33.9 - 17) / 1000) * 0.92 * 1.14 * 0.125

= 0.0022 kW

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes[624]:

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

Where:

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

= 53%[625] for interior or unknown location

= 0% for exterior or unheated location

0.03412 = Converts kWh to Therms

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

= 74%[626]

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	85%[627]

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[622] Based on Itron eShapes lighting loadprofiles.

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

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

[625] This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.

[626] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

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

For example, for a 900 lumen 17W standard CFL in an unknown location:

ΔTherms = - ((((33.9 - 17) / 1000) * 0.92 * 973 * 0.53 * 0.03412) / 0.74) * 0.85

= - 0.31 Therms

PEAK GAS SAVINGS

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[628]

For example, for a 900 lumen 17W standard CFL in an unknown location:

ΔPeakTherms = - 0.31 /217

= -0.0014 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

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

Installation Location	Replacement Period (years)[629]	Replacement Cost
Residential Interior and in-unit Multifamily	4.7	$2.17 for bulbs <2,000 lumens $3.44 for bulbs ≥2,000 lumens
Exterior	1.7	
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	4.3	

[628] Number of days where HDD 60 >0.

[629] 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). Assumed lifetime of CFL is 10,000 and of LED is 20,000 hours. Values provided are an average based on 70% incandescent/halogen, 25% CFL and 5% LED (blended average of 4200 hours).

[630] Incandescen/halogen and CFL costs based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year's worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; "Energy Savings Potential of Solid-State Lighting in General Illumination Applications", Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle. Baseline based on 70% Incandescent/halogen, 25% CFL and 5% LED.

MEASURE CODE: RS-LTG-ESCF-V01-170101

SUNSET DATE: 1/1/2018

2.5.2 Compact Fluorescent Lamp – Specialty

NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2017. IT SHOULD NOT BE USED BEYOND THAT DATE BUT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES.

DESCRIPTION

An ENERGY STAR qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb.

This characterization provides assumptions for when the CFL is installed in a known location (i.e., residential and in-unit interior or exterior) or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program or efficiency kit), an unknown residential location assumption is provided. For upstream programs, utilities should develop an assumption of the Residential vs Nonresidential split and apply the relevant assumptions to each portion.

The Technical Advisory Committee approved assuming a blended baseline condition of EISA qualified incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

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

ENERGY STAR qualified specialty CFL bulb based upon the v1.1 ENERGY STAR specification for lamps (http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf). Note a new ENERGY STAR specification v2.0 will become effective on 1/2/2017 (https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf).

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 80% EISA qualified halogen or incandescent and 10% CFL and 10% LED[631]. Lamp types include those exempt from the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (≤40W equivalent (We)), candelabra base (≤60We), vibration service bulb, decorative candle with medium or intermediate base (≤40We), 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 >40We), candle (shapes B, BA, CA >40We), candelabra base lamps (>60We), and intermediate base lamps (>40We).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be as follows:

Installation Location	Measure Life (years)[632]
Residential Interior and in-unit Multifamily	11.2
Exterior	4.0
Unknown (e.g., Retail, Upstream and Efficiency Kits)	10.3

[631] As proposed and discussed by Iowa TRM Oversight Committee and Technical Advisory Committee.
[632] Based on dividing hours of use assumptions with rated life assumption of 10,000 hours as per ENERGY STAR v1.1 requirements.

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs[633]:

Bulb Type	CFL Wattage	CFL	Incandescent	LED	Blended Baseline[634]	Incremental Cost
Directional	< 20W	$7.84	$6.31	$14.52	$7.28	$0.56
	≥20W	$9.31		$45.85	$10.56	-$1.25
Decorative and Globes	<15W	$7.80	$3.92	$8.09	$4.73	$3.08
	≥15W	$8.15		$15.86	$5.54	$2.61

For other bulb types, or unknown, assume the incremental capital cost of $1.81 (blended baseline cost of $6.01 and efficient cost of $7.82[635]).

For the Direct Install measure, the full CFL cost should be used plus $10 labor[636]. However, actual program delivery costs should be used if available.

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

LOADSHAPE

Loadshape RE09 – Residential Indoor Lighting

Loadshape RE10 – Residential Outdoor Lighting

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$ = Based on lumens of CFL bulb installed and includes blend of incandescent/halogen[637], CFL and LED by weightings provided in table below[638]. Note that when an IA net-to-gross (NTG) factor is determined for this measure, this blended baseline should be replaced with the Incandescent/Halogen baseline only.

633 Incandescent/halogen and CFL costs are based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.
634 Assumes 80% Incandescent/halogen, 10% CFL and 10% LED.
635 Average of lower wattage bins.
636 Assumption based on 15 minutes (including portion of travel time) and $40 per hour.
637 Incandescent/Halogen wattage is based upon the ENERGY STAR specification for lamps (http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf) and the Energy Policy and Conservation Act of 2012.
638 Weightings were determined through discussions with the Technical Advisory Committee. These are based upon review of Itron socket saturation and inventory data, in addition to review of multiple other data sources on the lighting market in other jurisdictions.

$Watts_{EE}$ = Actual wattage of energy efficient specialty bulb purchased – If unknown, assume the following defaults[639]:

EISA exempt bulb types:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen 80%	$Watts_{EE}$ CFL 10%	LED 10%	$Watts_{Base}$	Delta Watts CFL
EISA Exempt	3-Way	250	449	25	6.4	6.4	21.3	14.9
		450	799	40	11.4	11.4	34.3	22.9
		800	1,099	60	13.0	10.0	50.3	37.3
		1,100	1,599	75	20.8	13.1	63.4	42.6
		1,600	1,999	100	26.0	19.4	84.5	58.6
		2,000	2,549	125	32.2	35.0	106.7	74.5
		2,550	2,999	150	40.0	42.7	128.3	88.3
	Globe (medium and intermediate bases less than 750 lumens)	90	179	10	3.0	3.0	8.6	5.6
		180	249	15	4.8	4.8	13.0	8.2
		250	349	25	6.7	4.1	21.1	14.4
		350	749	40	9.9	6.5	33.6	23.7
	Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10	1.8	1.8	8.4	6.6
		90	149	15	2.7	2.7	12.5	9.9
		150	299	25	5.0	3.7	20.9	15.9
		300	749	40	7.5	5.3	33.3	25.7
	Globe (candelabra bases less than 1050 lumens)	90	179	10	3.0	3.0	8.6	5.6
		180	249	15	4.8	4.8	13.0	8.2
		250	349	25	6.7	4.1	21.1	14.4
		350	499	40	9.4	4.8	33.4	24.0
		500	1,049	60	15.5	7.0	50.2	34.8
	Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10	1.8	1.8	8.4	6.6
		90	149	15	2.7	2.7	12.5	9.9
		150	299	25	5.0	3.0	20.8	15.8
		300	499	40	7.7	4.7	33.2	25.6
		500	1,049	60	15.5	6.9	50.2	34.7

Directional Lamps – For Directional R, BR, and ER lamp types[640]:

[639] $Watts_{EE}$ defaults are based upon the average available ENERGY STAR product, accessed 06/18/2015. For any lamp type / lumen range where there is no ENERGY STAR product currently available, $Watts_{EE}$ is based upon the ENERGY STAR minimum luminous efficacy (Omnidirectional; 55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts, Directional; 40Lm/W for lamps with rated wattages less than 20Wand 50 Lm/W for lamps with rated wattages ≥ 20 watts and Decorative; 45Lm/W for lamps with rated wattages less than 15W, 50lm/W for lamps ≥15 and <25W, 60 Lm/W for ≥ 25 watts) for the mid-point of the lumen range. See calculation at "cerified-light-bulbs-2015-06-18.xlsx". These assumptions should be reviewed regularly to ensure they represent the available product.

[640] From pg 11 of the Energy Star Specification for lamps v1.1.

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	$Watts_{EE}$ CFL	LED	$Watts_{Base}$	Delta Watts CFL
				80%	10%	10%		
Directional	R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40	11.0	7.5	33.9	22.9
		473	524	45	12.5	7.9	38.0	25.6
		525	714	50	14.9	9.1	42.4	27.5
		715	937	65	15.6	12.6	54.8	39.2
		938	1,259	75	21.1	16.1	63.7	42.6
		1,260	1,399	90	23.0	17.8	76.1	53.1
		1,400	1,739	100	31.4	19.2	85.1	53.7
		1,740	2,174	120	39.1	25.6	102.5	63.3
		2,175	2,624	150	48.0	28.8	127.7	79.7
		2,625	2,999	175	56.2	56.2	151.2	95.0
		3,000	4,500	200	75.0	75.0	175.0	100.0
	*R, BR, and ER with medium screw bases w/ diameter ≤2.25"	400	449	40	10.6	6.3	33.7	23.1
		450	499	45	11.9	6.8	37.9	26.0
		500	649	50	14.4	7.3	42.2	27.8
		650	1,199	65	18.5	13.3	55.2	36.7
	*ER30, BR30, BR40, or ER40	400	449	40	10.6	10.6	34.1	23.5
		450	499	45	11.9	11.9	38.4	26.5
		500	649	50	14.4	12.0	42.6	28.3
	*BR30, BR40, or ER40	650	1,419	65	18.0	12.4	55.0	37.1
	*R20	400	449	40	10.6	10.6	34.1	23.5
		450	719	45	12.5	7.7	38.0	25.5
	*All reflector lamps below lumen ranges specified above	200	299	20	6.2	4.0	17.0	10.8
		300	399	30	8.7	6.2	25.5	16.8

Directional lamps are exempt from EISA regulations.

EISA non-exempt bulb types:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	$Watts_{EE}$ CFL	LED	$Watts_{Base}$	Delta Watts CFL
				80%	10%	10%		
EISA Non-Exempt	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)	250	309	25	5.1	4.1	20.9	15.8
		310	749	29	9.5	6.6	24.8	15.3
		750	1049	43	13.5	10.1	36.8	23.3
		1050	1489	53	18.9	12.8	45.6	26.6
		1490	2600	72	24.8	17.4	61.8	37.0

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

Program		# of bulbs	Discounted In Service Rate (ISR)[641]
Retail (Time of Sale)[642]			92%
Direct Install[643]			97%
Efficiency Kits	School Kits[644]	1	57%
		2	48%
		3	42%
		Unknown[645]	49%
	EnergyWise (Low Income)[646]	1	79%
		2	74%
		Unknown[647]	76.5%

Hours = Average hours of use per year, varies by bulb type as presented below:

Installation Location	Hours
Residential Interior and in-unit Multifamily	894[648]
Exterior	2,475 [649]
Unknown (e.g., Retail, Upstream and Efficiency Kits)	973[650]

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section)

= 1 - ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.94[651]

Where:

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

= 53%[652] for interior or unknown location

= 0% for exterior or unheated location

[641] All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%); see "Res Lighting ISR calculation.xlsx" for more information.
[642] In service rate for Retail CFLs is based upon recommendation in the Uniform Methods Project to use data from the Navigant Consulting and Apex Analytics (2013) study.
[643] Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys; http://www.ilsag.info/evaluation-documents.html
[644] Based on results provided in "School-based interim process memo_Final_100215.doc".
[645] Average of above.
[646] Based on Cadmus, "Final Report: Iowa 2015 Energy Wise Program", January 29, 2016, p16.
[647] Average of above.
[648] Average of four Midwest metering studies: 2011 Ameren Missouri Lighting and Appliance Evaluation – PY 2; 2012 Consumers Energy - Technical Memo; 2012 DTE - Technical Memo; and PY5/PY6 ComEd, Illinois Residential Lighting Program evaluation.
[649] Based on secondary research conducted as part of the Illinois PY5/PY6 ComEd Residential Lighting Program evaluation.
[650] Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.
[651] Calculated using defaults: 1-((0.53/1.38) * 0.15) = 0.94.
[652] This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington.

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

= Actual – If not available, use[653]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 and after	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.38[654]

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	15%[655]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[656]
Building without cooling or exterior	1.0
Unknown	1.08[657]

For example, for a lamp sold through a retail program, an 800 lumen R lamp with medium screw base with 2.5" diameter:

ΔkWh = ((54.8 – 15.6) / 1000) * 0.92 * 973 * (0.94 + (1.08 – 1))

= 35.8 kWh

[653] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 and 2015 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[654] Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on assumption 50% are units from before 2006 and 50% 2006-2014.

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

[656] The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). Based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm ($-0.02 * SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

[657] The value is estimated at 1.09 (calculated as 1 + (0.64*(0.34 / 2.8)). Based on assumption that 64% of homes have central cooling (based on 2009 Residential Energy Consumption Survey, see "HC7.9 Air Conditioning in Midwest Region.xls").

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * WHFdCool * CF$$

Where:

WHFdCool = Waste Heat Factor for demand to account for cooling savings from efficient lighting.

Bulb Location	WHFdCool
Building with cooling	1.22[658]
Building without cooling or exterior	1.0
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1.14[659]

CF = Summer peak Coincidence Factor for measure.

Bulb Location	CF
Residential Interior and in-unit Multifamily [660]	13.1%
Exterior [661]	1.8%
Unknown (e.g., Retail, Upstream, and Efficiency Kits)[662]	12.5%

Other factors as defined above

For example, for a lamp sold through a retail program, an 800 lumen R lamp with medium screw base with 2.5" diameter:

ΔkW = ((54.8 – 15.6) / 1,000) * 0.92 * 1.14 * 0.125

= 0.0051 kW

Natural Gas Savings

Heating Penalty for Natural Gas heated homes[663]:

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

Where:

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

= 53%[664] for interior or unknown location

[658] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour) consistent with the lighting peak hours.
[659] The value is estimated at 1.14 (calculated as 1 + (0.64 * 0.61 / 2.8)).
[660] Based on analysis of loadshape data provided by Cadmus.
[661] Based on Itron eShapes lighting loadprofiles.
[662] Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.
[663] Negative value because this is an increase in heating consumption due to the efficient lighting.
[664] This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.

= 0% for exterior location

0.03412 =Converts kWh to Therms

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

=74%[665]

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	85%[666]

For example, for a lamp sold through a retail program, an 800 lumen R lamp with medium screw base with 2.5" diameter:

ΔTherms = - ((((54.8 – 15.6) / 1000) * 0.92 * 973 * 0.53 * 0.03412) / 0.74) * 0.85

= - 0.7 Therms

PEAK GAS SAVINGS

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[667]

For example, using default assumptions provided in the example above:

ΔPeakTherms = - 0.7 /217

= -0.0032 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[665] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

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

[667] Number of days where HDD 60 >0.

DEEMED O&M COST ADJUSTMENT CALCULATION

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

Bulb Type	Installation Location	Replacement Period (years)	Replacement Cost[668]
Directional	Residential Interior and in-unit Multifamily	4.8	$7.28 for < 20W, $10.56 for ≥20W
	Exterior	1.7	
	Unknown (e.g., Retail, Upstream, and Efficiency Kits)	4.4	
Decorative/Globe	Residential Interior and in-unit Multifamily	3.7	$4.73 for <15W, $5.54 for ≥15W
	Exterior	1.3	
	Unknown (e.g., Retail, Upstream, and Efficiency Kits)	3.4	
Unknown	Residential Interior and in-unit Multifamily	4.3	$6.01
	Exterior	1.5	
	Unknown (e.g., Retail, Upstream, and Efficiency Kits)	3.9	

MEASURE CODE: RS-LTG-ESCS-V01-170101

SUNSET DATE: 1/1/2018

[668] Incandescen/halogen and CFL costs based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle. Baseline based on 80% Incandescent/halogen, 10% CFL and 10% LED.

[669] 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). Assumed lifetime of CFL is 10,000 and of LED is 25,000 hours. Values provided are an average based on 80% incandescent/halogen, 10% CFL and 10% LED (blended average of 4300 hours).

[670] Assumed rated life of incandescent/halogen is 1000 hours, CFL is 10,000 and decorative LED is 15,000 hours. Values provided are an average based on 80% incandescent/halogen, 10% CFL and 10% LED (blended average of 3300 hours).

[671] Values provided are an average of directional and decorative (blended average of 3800 hours).

2.5.3 LED Lamp – Standard

Description

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

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard. Furthermore, the Technical Advisory Committee approved assuming a blended baseline condition of EISA qualified incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt. However, the Iowa TAC agreed to delay this baseline shift to January 1, 2021.[672]

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

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

Definition of Efficient Equipment

In order for this characterization to apply, new lamps must be ENERGY STAR labeled based upon the v2.1 ENERGY STAR specification for lamps (https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification_1.pdf) or CEE Tier 2 qualified. Specifications are as follows:

Efficiency Level	Lumens / watt	
	CRI<90	CRI≥90
ENERGY STAR v2.1	80	70
CEE Tier 2[673]	95	80

Qualification could also be based on the Design Light Consortium's qualified product list[674].

Definition of Baseline Equipment

The baseline condition for this measure is assumed to be a blend of 55% EISA qualified halogen or incandescent and

[672] The Iowa TAC agreed to delay the EISA baseline shift to 2021 to account for customers purchasing final halogen bulbs shortly before the 2020 provision comes in to effect, potentially stockpiling, an apparent lack of enforcement, political uncertainty, and experience with other standard changes where supposedly non-conforming product has remained readily available for a number of years.

[673] Also required to have rated life of 25,000 hours and dimming capability.

[674] https://www.designlights.org/QPL

13% CFL and 32% LED[675]. From 2021 the baseline is assumed to rise to 70 lumens / watt[676] and therefore a midlife adjustment is provided.

Deemed Lifetime of Efficient Equipment

The rated life of omnidirectional LED lamps is assumed to be 21,283[677]. This would imply a lifetime of 20 years for Residential interior and 9 years for Residential exterior; however, all installations are capped at 10 years[678] so interior bulbs should assume a 10-year measure life.

Deemed Measure Cost

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs[679]:

Lamp Type	CRI	Product Type	Cost	Incremental Cost
Standard A-lamp	<90	Baseline	$1.97	n/a
		ESTAR LED	$3.16	$1.19
		CEE T2 LED	$3.29	$1.32
	>=90	Baseline	$2.16	n/a
		ESTAR LED	$3.67	$1.51
		CEE T2 LED	$3.75	$1.58

Loadshape

Loadshape RE09 – Residential Indoor Lighting

Loadshape RE10 – Residential Outdoor Lighting

Algorithm

Calculation of Savings

Electric Energy Savings

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

Where:

$Watts_{Base}$ = Based on lumens of LED bulb installed and includes blend of incandescent/halogen[680], CFL and LED by weightings provided in table below[681]. Note that when an IA net-to-gross

[675] Based on 2016 Q3 lamp shipment data from NEMA; http://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx. Note this is consistent with the findings from the Dunsky baseline study, but adjusted to account for significant growth in LED market and reduction in CFL.

[676] 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. However with the rapid decline in CFL sales and increase in LEDs, 70 lumens per watt represents an estimated mix of CFL and non-ENERGY STAR LED.

[677] Average rated life of omnidirectional bulbs on the ENERGY STAR qualified products list as of June 5, 2018..

[678] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18. Particularly in residential applications, lamps are susceptible to persistence issues such as removal, new occupants etc.

[679] Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017. See "2017 LED Measure Cost and O&M Calc.xls" for more information.

[680] Incandescent/Halogen wattage is based upon the post first phase of EISA wattage.

[681] Weightings were determined through discussions with the Technical Advisory Committee. These are based on 2016 Q3 lamp shipment data from NEMA; http://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx. Note this is consistent with the

(NTG) factor is determined for this measure, this blended baseline should be replaced with the Incandescent/Halogen baseline only.

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

Lower Lumen Range	Upper Lumen Range	Inc/ Halogen	CFL[682]	LED[683]	$Watts_{Base}$	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
		55%	15%	30%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90	CRI >=90
250	309	25	4.7	3.7	15.6	3.5	4.0	2.9	3.5	12.1	11.6	12.6	12.1
310	749	29	8.8	7.1	19.4	6.6	7.6	5.6	6.6	12.8	11.8	13.8	12.8
750	1049	43	15.0	12.0	29.5	11.2	12.9	9.5	11.2	18.3	16.6	20.0	18.3
1050	1489	53	21.2	16.9	37.4	15.9	18.1	13.4	15.9	21.5	19.3	24.0	21.5
1490	2600	72	34.1	27.3	52.9	25.6	29.2	21.5	25.6	27.3	23.7	31.4	27.3
2601	3300	150	49.2	39.3	101.7	36.9	42.2	31.1	36.9	64.8	59.5	70.6	64.8
3301	3999	200	60.8	48.7	133.7	45.6	52.1	38.4	45.6	88.1	81.6	95.3	88.1
4000	6000	300	83.3	66.7	197.5	62.5	71.4	52.6	62.5	135.0	126.1	144.9	135.0

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

Program		Discounted In Service Rate (ISR)[684]
Retail (Time of Sale)[685]		90%
Direct Install[686]		97%
Efficiency Kits	School Kits[687]	60%
	EnergyWise (Low Income)[688]	79%

Hours = Average hours of use per year

Installation Location	Hours
Residential Interior and in-unit Multifamily	1,088[689]
Exterior	2,475[690]

findings from the Dunsky baseline study, but adjusted to account for significant growth in LED market and reduction in CFL.

682 Baseline CFL watts are calculated using the midpoint of the lumen range and an assumed efficacy of 60 lumens/watt.

683 Baseline LED watts are calculated using the midpoint of the lumen range and an assumed efficacy of 75 lumens/watt.

684 All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%). The second and third year installations rates are from NREL, "Chapter 6: Residential Lighting Evaluation Protocol of the Uniform Methods Project," October 2017. See "Res Lighting ISR calculation_2019.xlsx" for more information.

685 1st year in service rate is a 2-year weighted average of ComEd PY7, PY8 and PY9 intercept data.'

686 Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys. http://www.ilsag.info/evaluation-documents.html

687 In Service Rates provided are for the bulb within a kit only. Kits provided free to students through school, with education program. 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

688 Based on Cadmus, "Final Report: Iowa 2015 Energy Wise Program", January 29, 2016, p16.

689 Based on recommended value for standard LED lamps (2.98) in interior locations from Opinion Dynamics "Illinois Statewide Residential LED Hours of Use Study Additional Results," April 17, 2018.

690 Based on secondary research conducted as part of the Illinois PY5/PY6 ComEd Residential Lighting Program evaluation.

Installation Location	Hours
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1,157[691]

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section).

= 1 – ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.93[692]

Where:

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

= 53%[693] for interior or unknown location

= 0% for exterior or unheated location

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

= Actual system efficiency including duct loss – If not available, use[694]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 – 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.27[695]

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	17%[696]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat

691 Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.
692 Calculated using defaults; 1-((0.53/1.27) * 0.17) = 0.93.
693 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.
694 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.
695 Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.
696 Based on Dunsky and Opinion Dynamics Baseline Study results.

from efficient lighting.

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[697]
Building without cooling or exterior	1.0
Unknown	1.11[698]

Mid-Life Baseline Adjustment

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Under the EISA backstop provision, the minimum efficacy of bulbs that can be sold is 45 lumens per watt, in essence making the baseline bulb a CFL equivalent from 2020 (except for <310 and 3300+ lumen lamps). However, the Iowa TAC agreed to delay this baseline shift to 2021.[699]

This reduced annual savings will need to be incorporated in to cost effectiveness screening calculations. The baseline adjustment also impacts the O&M schedule.

For example, for 43W equivalent LED lamp installed in 2019, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

Lower Lumen Range	Upper Lumen Range	Mid Lumen Range	WattsBase after EISA 2020[700]	%Adj in 2021 ESTAR		%Adj in 2021 CEE T2	
				CRI <90	CRI >=90	CRI <90	CRI >=90
250	309	280	15.6	100%	100%	100%	100%
310	749	530	7.6	7%	0%	14%	7%
750	1049	900	12.9	9%	0%	17%	9%
1050	1489	1270	18.1	11%	0%	20%	11%
1490	2600	2045	29.2	13%	0%	25%	13%
2,601	3,300	2,775	42.2	8%	0%	16%	8%
3,301	3,999	3,500	133.7	100%	100%	100%	100%
4,000	6,000	5,000	197.5	100%	100%	100%	100%

697 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). Based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * $SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

698 The value is estimated at 1.11 (calculated as 1 + (0.88*(0.34 / 2.8)). Based on assumption that 88% of homes have central cooling (based on Dunsky and Opinion Dynamics Baseline Study results).

699 The Iowa TAC agreed to delay the EISA baseline shift to 2021 to account for customers purchasing final halogen bulbs shortly before the 2020 provision comes in to effect, potentially stockpiling, an apparent lack of enforcement, political uncertainty, and experience with other standard changes where supposedly non-conforming product has remained readily available for a number of years.

700 Baseline post 2020 watts are calculated using the midpoint of the lumen range and an assumed efficacy of 70 lumens/watt.. 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. However with the rapid decline in CFL sales and increase in LEDs, 70 lumens per watt represents an estimated mix of CFL and non-ENERGY STAR LED.

> **For example**, a 11W LED lamp, 900 lumens, CRI 85, is purchased through retail in 2019:
>
> ΔkWh = ((29.5 – 11) /1000) * 0.90 * 1,157 * (0.93 + (1.11 – 1))
>
> = 20.0 kWh
>
> This value should be claimed for two years, but from 2021 until the end of the measure life for that same lamp, savings should be reduced to (20.0 * 0.09 =) 1.8 kWh for the remainder of the measure life. Note these adjustments should be applied to kW and fuel impacts as well.

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * WHFdCool * CF$$

Where:

WHFdCool = Waste Heat Factor for demand to account for cooling savings from efficient lighting.

Bulb Location	WHFdCool
Building with cooling	1.22[701]
Building without cooling or exterior	1.0
Unknown (e.g. Retail, Upstream and Efficiency Kits)	1.19[702]

CF = Summer peak Coincidence Factor for measure.

Bulb Location	CF
Residential Interior and in-unit Multifamily [703]	13.1%
Exterior [704]	1.8%
Unknown (e.g., Retail, Upstream, and Efficiency Kits)[705]	12.5%

Other factors as defined above

> **For example**, for a 11W LED lamp, 900 lumens, purchased through retail in 2019:
>
> ΔkW = ((29.5 – 11) /1000) * 0.90 * 1.19 * 0.125
>
> = 0.0025 kW

Natural Gas Savings

Heating Penalty for Natural Gas heated homes[706]:

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

[701] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour) consistent with the lighting peak hours.

[702] The value is estimated at 1.19 (calculated as 1 + (0.88 * 0.61 / 2.8)).

[703] Based on analysis of loadshape data provided by Cadmus.

[704] Based on Itron eShapes lighting loadprofiles.

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

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

Where:

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

= 53%[707] for interior or unknown location

= 0% for exterior or unheated location

0.03412 =Converts kWh to Therms

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

=74%[708]

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83%[709]

For example, for a 11W LED lamp, 900 lumens, purchased through retail in 2019:

ΔTherms = - ((((29.5 - 11) / 1000) * 0.90 * 1,157 * 0.53 * 0.03412) / 0.74) * 0.83

= - 0.39 therms

PEAK GAS SAVINGS

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[710]

For example, for a 11W LED lamp, 900 lumens, purchased through retail in 2019:

ΔPeakTherms = - 0.39 /217

= -0.0018 therms

[707] This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.

[708] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

[709] Based on Dunsky and Opinion Dynamics Baseline Study results

[710] Number of days where HDD 60 >0.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

In order to account for the shift in baseline due to the backstop provision of the Energy Independence and Security Act of 2007, requiring all standard bulbs (except for <310 and 3300+ lumen lamps) to have an efficacy equivalent to today's CFL, an annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. Bulb replacement costs assumed in the O&M calculations are provided below[711].

CRI	Product Type	Cost
<90	Inc/Hal	$1.40
	CFL	$1.68
	LED	$3.16
>=90	Inc/Hal	$1.40
	CFL	$1.95
	LED	$3.67

The present value of replacement lamps and annual levelized replacement costs using the statewide real discount rate of 7.20% are presented below[712]:

		PV of replacement costs for period		Levelized annual replacement cost savings	
CRI	Location	2020 Installs	2021 Installs	2020 Installs	2021 Installs
<90	Residential and in-unit Multifamily	$1.88	$1.29	$0.27	$0.18
	Exterior	$4.24	$3.00	$0.61	$0.43
	Unknown	$1.89	$1.52	$0.27	$0.22
>=90	Residential and in-unit Multifamily	$2.07	$1.84	$0.30	$0.18
	Exterior	$4.59	$3.14	$0.66	$0.31
	Unknown	$2.08	$2.37	$0.30	$0.24

Note: incandescent lamps in lumen range <310 and >3300 are exempt from EISA. For these bulb types, an O&M cost should be applied as follows:

[711] Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017 and equivalent baseline bulbs.
[712] See "2019 LED Measure Cost and O&M Calc.xlsx" for more information.

Installation Location	Replacement Period (years)[713]	Replacement Cost
Residential Interior and in-unit Multifamily	7.8	$1.97
Exterior	3.4	
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	7.3	

MEASURE CODE: RS-LTG-LEDA-V05-200101

SUNSET DATE: 1/1/2021

[713] 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). Assumed lifetime of CFL is 10,000 and of LED is 21,283 hours. Values provided are an average based on 55% incandescent/halogen, 15% CFL and 30% LED (blended average of 8,435 hours).

2.5.4 LED Lamp – Specialty

Description

This characterization provides savings assumptions for LED Directional, Decorative, and Globe lamps. This characterization provides assumptions for when the LED is installed in a known location (i.e., residential and in-unit interior or exterior) or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program or efficiency kit), an unknown residential location assumption is provided. For upstream programs, utilities should develop an assumption of the Residential v Nonresidential split and apply the relevant assumptions to each portion.

The Technical Advisory Committee approved assuming a blended baseline condition of incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

A DOE Final Rule released on 1/19/2017 updated the definition of General Service Lamps (GSL) as provided in the 2009 Energy Independence and Security Act (EISA) such that the lamp types characterized in this measure became subject to the backstop provision in EISA, which requires that after January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt.

On 2/6/2019 DOE released a Notice of Proposed Rulemaking that attempts to withdraw this expansion of the GSL definition, reverting to the prior definition that was limited to A-lamps. The expectation is that a Final Rule will be released later in 2019. Since the original EISA legislation included anti-backsliding provisions, it is expected that multiple lawsuits will quickly be initiated once a Final Rule is released. This leads to significant uncertainty around the final application of the EISA backstop provision, whether the expanded definition will hold, as well as uncertainty regarding how the market for these LED products would grow regardless of the backstop outcome.

To account for this uncertainty, the 2020 version of this measure delays application of the midlife adjustment associated with the baseline shift to 1/1/2025.

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

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

Definition of Efficient Equipment

In order for this characterization to apply, new lamps must be ENERGY STAR labeled based upon the v2.1 ENERGY STAR specification for lamps (https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification_1.pdf) or CEE Tier 2 qualified. Specifications are as follows:

Efficiency Level	Lamp Type	Lumens / watt	
		CRI<90	CRI≥90
ENERGY STAR v2.1	Directional	70	61
	Decorative / Globe	65	65
CEE Tier 2[714]	Directional	85	70
	Decorative / Globe	95	80

Qualification could also be based on the Design Light Consortium's qualified product list[715].

[714] Also required to have dimming capability.
[715] https://www.designlights.org/QPL

Definition of Baseline Equipment

The baseline condition for this measure is assumed to be a blend of 80% EISA qualified halogen or incandescent and 10% CFL and 10% LED[716]. Lamp types include those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (≤40W equivalent (We)), candelabra base (≤60We), vibration service bulb, decorative candle with medium or intermediate base (≤40We), 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 >40We), candle (shapes B, BA, CA >40We), candelabra base lamps (>60We), and intermediate base lamps (>40We). Note however that all lamps are subject to a baseline shift to account for the current EISA regulation which removes exemptions for these bulbs. However due to the uncertainty this adjustment is applied in 2025.

Deemed Lifetime of Efficient Equipment

The rated life for directional bulbs is assumed to be 25,128 and for decorative bulbs, 18,719 hours[717]. This would imply a lifetime of 33 years for residential interior directional, 10 years for residential exterior directional, 24.5 years for residential interior decorative, and 7.6 years for residential exterior decorative; however, all installations are capped at 10 years[718].

Deemed Measure Cost

Wherever possible, actual incremental costs should be used. If unavailable assume the following incremental costs[719]:

Bulb Type	CRI	Product Type	Cost	Incremental Cost
Directional	<90	Baseline	$5.38	n/a
		ESTAR LED	$7.80	$2.42
		CEE T2 LED	$18.96	$13.58
	>=90	Baseline	$5.36	n/a
		ESTAR LED	$7.63	$2.26
		CEE T2 LED	$18.54	$13.18
Decorative	<90	Baseline	$3.55	n/a
		ESTAR LED	$7.50	$3.95
		CEE T2 LED	$7.83	$4.28
	>=90	Baseline	$3.67	n/a
		ESTAR LED	$8.69	$5.02
		CEE T2 LED	$9.08	$5.41

Loadshape

Loadshape RE09 – Residential Indoor Lighting

Loadshape RE10 – Residential Outdoor Lighting

716 As proposed and discussed by Iowa TRM Oversight Committee and Technical Advisory Committee.

717 Average rated life of directional and decorative bulbs on the ENERGY STAR qualified products list as of June 5, 2018.

718 Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations, and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18. Particularly in residential applications, lamps are susceptible to persistence issues such as removal, new occupants, etc.

719 Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017. See "2017 LED Measure Cost and O&M Calc.xls" for more information.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$ = Based on lumens of LED bulb installed and includes blend of incandescent/halogen[720], CFL and LED by weightings provided in table below[721]. Note that when an IA net-to-gross (NTG) factor is determined for this measure, this blended baseline should be replaced with the Incandescent/Halogen baseline only.

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below[722]:

[720] Incandescent/Halogen wattage is based upon the ENERGY STAR specification for lamps (http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf) and the Energy Policy and Conservation Act of 2012.

[721] Weightings were determined through discussions with the Technical Advisory Committee. These are based upon review of Itron socket saturation and inventory data, in addition to review of multiple other data sources on the lighting market in other jurisdictions.

[722] $Watts_{EE}$ defaults are based upon the ENERGY STAR minimum luminous efficacy (for the mid-point of the lumen range. See calculations in file "2017 Lighting Updates and Baseline Estimates"..

EISA exempt bulb types:

	Bulb Type	Lower Lumen Range	Upper Lumen Range	Inc/ Hal	$Watts_{EE}$ CFL	$Watts_{EE}$ LED	$Watts_{Base}$	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
				80%	10%	10%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90	CRI >=90
EISA Exempt	3-Way[723]	250	449	25	6.4	6.4	21.3	4.4	5.0	3.7	4.4	16.9	16.3	17.6	16.9
		450	799	40	11.4	11.4	34.3	7.8	8.9	6.6	7.8	26.5	25.4	27.7	26.5
		800	1,099	60	13.0	10.0	50.3	11.9	13.6	10.0	11.9	38.4	36.7	40.3	38.4
		1,100	1,599	75	20.8	13.1	63.4	16.9	19.3	14.2	16.9	46.5	44.1	49.2	46.5
		1,600	1,999	100	26.0	19.4	84.5	22.5	25.7	18.9	22.5	62.0	58.8	65.6	62.0
		2,000	2,549	125	32.2	35.0	106.7	28.4	32.5	23.9	28.4	78.3	74.2	82.8	78.3
		2,550	2,999	150	40.0	42.7	128.3	34.7	39.6	29.2	34.7	93.6	88.6	99.1	93.6
	Globe (medium and intermediate base < 750 lumens)	90	179	10	3.0	3.0	8.6	2.1	2.1	1.4	1.7	6.5	6.5	7.2	6.9
		180	249	15	4.8	4.8	13.0	3.3	3.3	2.3	2.7	9.7	9.7	10.7	10.3
		250	349	25	6.7	4.1	21.1	4.6	4.6	3.2	3.7	16.5	16.5	17.9	17.3
		350	749	40	9.9	6.5	33.6	8.5	8.5	5.8	6.9	25.2	25.2	27.9	26.8
	Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10	1.8	1.8	8.4	1.2	1.2	0.8	1.0	7.1	7.1	7.5	7.4
		90	149	15	2.7	2.7	12.5	1.8	1.8	1.3	1.5	10.7	10.7	11.3	11.0
		150	299	25	5.0	3.7	20.9	3.5	3.5	2.4	2.8	17.4	17.4	18.5	18.1
		300	749	40	7.5	5.3	33.3	8.1	8.1	5.5	6.6	25.2	25.2	27.8	26.7
	Globe (candelabra bases less than 1050 lumens)	90	179	10	3.0	3.0	8.6	2.1	2.1	1.4	1.7	6.5	6.5	7.2	6.9
		180	249	15	4.8	4.8	13.0	3.3	3.3	2.3	2.7	9.7	9.7	10.7	10.3
		250	349	25	6.7	4.1	21.1	4.6	4.6	3.2	3.7	16.5	16.5	17.9	17.3
		350	499	40	9.4	4.8	33.4	6.5	6.5	4.5	5.3	26.9	26.9	29.0	28.1
		500	1,049	60	15.5	7.0	50.2	11.9	11.9	8.2	9.7	38.3	38.3	42.1	40.6
	Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10	1.8	1.8	8.4	1.2	1.2	0.8	1.0	7.1	7.1	7.5	7.4
		90	149	15	2.7	2.7	12.5	1.8	1.8	1.3	1.5	10.7	10.7	11.3	11.0
		150	299	25	5.0	3.0	20.8	3.5	3.5	2.4	2.8	17.3	17.3	18.4	18.0
		300	499	40	7.7	4.7	33.2	6.1	6.1	4.2	5.0	27.1	27.1	29.0	28.2
		500	1,049	60	15.5	6.9	50.2	11.9	11.9	8.2	9.7	38.3	38.3	42.1	40.6

[723] For 3-way bulbs or fixtures, the product's median lumens value will be used to determine both LED and baseline wattages.

Directional Lamps – For Directional R, BR, and ER lamp types[724]:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Watts_{EE} CFL	Watts_{EE} LED	Watts_{Base}	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
				80%	10%	10%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90	CRI >=90
Directional	R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40	11.0	7.5	33.9	6.4	7.3	5.2	6.4	27.5	26.5	28.6	27.5
		473	524	45	12.5	7.9	38.0	7.1	8.2	5.9	7.1	30.9	29.9	32.2	30.9
		525	714	50	14.9	9.1	42.4	8.9	10.2	7.3	8.9	33.6	32.2	35.1	33.6
		715	937	65	15.6	12.6	54.8	11.8	13.5	9.7	11.8	43.0	41.3	45.1	43.0
		938	1,259	75	21.1	16.1	63.7	15.7	18.0	12.9	15.7	48.0	45.7	50.8	48.0
		1,260	1,399	90	23.0	17.8	76.1	19.0	21.8	15.6	19.0	57.1	54.3	60.4	57.1
		1,400	1,739	100	31.4	19.2	85.1	22.4	25.7	18.5	22.4	62.6	59.3	66.6	62.6
		1,740	2,174	120	39.1	25.6	102.5	28.0	32.1	23.0	28.0	74.5	70.4	79.4	74.5
		2,175	2,624	150	48.0	28.8	127.7	34.3	39.3	28.2	34.3	93.4	88.3	99.5	93.4
		2,625	2,999	175	56.2	56.2	151.2	40.2	46.1	33.1	40.2	111.1	105.1	118.2	111.1
		3,000	4,500	200	75.0	75.0	175.0	53.6	61.5	44.1	53.6	121.4	113.5	130.9	121.4
	*R, BR, and ER with medium screw bases w/ diameter ≤2.25"	400	449	40	10.6	6.3	33.7	6.1	7.0	5.0	6.1	27.6	26.7	28.7	27.6
		450	499	45	11.9	6.8	37.9	6.8	7.8	5.6	6.8	31.1	30.1	32.3	31.1
		500	649	50	14.4	7.3	42.2	8.2	9.4	6.8	8.2	34.0	32.8	35.4	34.0
		650	1,199	65	18.5	13.3	55.2	13.2	15.2	10.9	13.2	42.0	40.0	44.3	42.0
	*ER30, BR30, BR40, or ER40	400	449	40	10.6	10.6	34.1	6.1	7.0	5.0	6.1	28.1	27.2	29.1	28.1
		450	499	45	11.9	11.9	38.4	6.8	7.8	5.6	6.8	31.6	30.6	32.8	31.6
		500	649	50	14.4	12.0	42.6	8.2	9.4	6.8	8.2	34.4	33.2	35.9	34.4
	*BR30, BR40, or ER40	650	1,419	65	18.0	12.4	55.0	14.8	17.0	12.2	14.8	40.3	38.1	42.9	40.3
	*R20	400	449	40	10.6	10.6	34.1	6.1	7.0	5.0	6.1	28.1	27.2	29.1	28.1
		450	719	45	12.5	7.7	38.0	8.4	9.6	6.9	8.4	29.7	28.4	31.1	29.7
	*All reflector lamps below lumen ranges specified above	200	299	20	6.2	4.0	17.0	3.6	4.1	2.9	3.6	13.5	12.9	14.1	13.5
		300	399	30	8.7	6.2	25.5	5.0	5.7	4.1	5.0	20.5	19.8	21.4	20.5

Directional lamps are exempt from first phase of EISA regulations, but not the backstop provision.

[724] From pg 13 of the Energy Star Specification for lamps v2.1.

EISA non-exempt bulb types:

	Bulb Type	Lower Lumen Range	Upper Lumen Range	Inc/ Hal	CFL	$Watts_{EE}$ LED	Watts Base	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
				80%	10%	10%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90	CRI >=90
EISA Non-Exempt	Dimmable Twist, Globe (<5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	250	309	25	5.1	4.1	20.9	3.5	4.0	2.9	3.5	17.4	16.9	18.0	17.4
		310	749	29	9.5	6.6	24.8	6.6	7.6	5.6	6.6	18.2	17.2	19.2	18.2
		750	1049	43	13.5	10.1	36.8	11.2	12.9	9.5	11.2	25.5	23.9	27.3	25.5
		1050	1489	53	18.9	12.8	45.6	15.9	18.1	13.4	15.9	29.7	27.4	32.2	29.7
		1490	2600	72	24.8	17.4	61.8	25.6	29.2	21.5	25.6	36.3	32.6	40.3	36.3

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

Program		Discounted In Service Rate (ISR)[725]
Retail (Time of Sale)[726]		90%
Direct Install[727]		97%
Efficiency Kits	School Kits[728]	60%
	EnergyWise (Low Income)[729]	79%

Hours = Average hours of use per year

Installation Location	Hours
Residential Interior and in-unit Multifamily	763[730]
Exterior	2,475 [731]
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1,020[732]

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section).

= 1 - ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.93[733]

Where:

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

= 53%[734] for interior or unknown location

= 0% for exterior or unheated location

[725] All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%). The second and third year installations rates are from NREL, "Chapter 6: Residential Lighting Evaluation Protocol of the Uniform Methods Project," October 2017. See "Res Lighting ISR calculation_2019.xlsx" for more information.

[726] 1st year in service rate is a weighted average of ComEd PY7, PY8 and PY9 intercept data.

[727] Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys. http://www.ilsag.info/evaluation-documents.html

[728] In Service Rates provided are for the bulb within a kit only. Kits provided free to students through school, with education program. 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

[729] Based on Cadmus, "Final Report: Iowa 2015 Energy Wise Program", January 29, 2016, p16.

[730]Based on recommended value for specialty LED lamps (2.09) in interior locations from Opinion Dynamics "Illinois Statewide Residential LED Hours of Use Study Additional Results," April 17, 2018.

[731] Based on secondary research conducted as part of the Illinois PY5/PY6 ComEd Residential Lighting Program evaluation.

[732] Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, finding 15% exterior specialty lighting.

[733] Calculated using defaults: 1-((0.53/1.27) * 0.17) = 0.93

[734] This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.

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

= Actual system efficiency including duct loss – If not available, use[735]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 – 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.27[736]

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	17%[737]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting.

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[738]
Building without cooling or exterior	1.0
Unknown	1.11[739]

Mid-Life Baseline Adjustment

During the lifetime of an LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. With the future uncertainty of appropriate baseline assumptions, the Iowa TAC agreed to apply this baseline shift in 2025.

This reduced annual savings will need to be incorporated in to cost effectiveness screening calculations. The baseline

735 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.

736 Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.

737 Based on Dunsky and Opinion Dynamics Baseline Study results.

738 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). Based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm ($-0.02 * SEER^2$) + (1.12 * SEER) (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

739 The value is estimated at 1.11 (calculated as 1 + (0.88*(0.34 / 2.8)). Based on assumption that 88% of homes have central cooling (based on Dunsky and Opinion Dynamics Baseline Study results).

adjustment also impacts the O&M schedule.

	Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase after EISA 2025[740]	%Adj in 2025 ESTAR		%Adj in 2025 CEE T2	
					CRI <90	CRI >=90	CRI <90	CRI >=90
Decorative	3-Way	250	449	5.0	4%	0%	7%	4%
		450	799	8.9	4%	0%	8%	4%
		800	1,099	13.6	4%	0%	9%	4%
		1,100	1,599	19.3	5%	0%	10%	5%
		1,600	1,999	25.7	5%	0%	10%	5%
		2,000	2,549	32.5	5%	0%	10%	5%
		2,550	2,999	39.6	5%	0%	11%	5%
	Globe (medium and intermediate base < 750 lumens)	90	179	2.4	6%	6%	14%	11%
		180	249	3.9	6%	6%	15%	12%
		250	349	5.4	5%	5%	13%	10%
		350	749	10.0	6%	6%	15%	12%
	Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	1.4	3%	3%	8%	6%
		90	149	2.2	3%	3%	8%	6%
		150	299	4.1	4%	4%	9%	7%
		300	749	9.5	6%	6%	14%	11%
	Globe (candelabra bases less than 1050 lumens)	90	179	2.4	6%	6%	14%	11%
		180	249	3.9	6%	6%	15%	12%
		250	349	5.4	5%	5%	13%	10%
		350	499	7.7	4%	4%	11%	9%
		500	1,049	14.1	6%	6%	14%	11%
	Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	1.4	3%	3%	8%	6%
		90	149	2.2	3%	3%	8%	6%
		150	299	4.1	4%	4%	9%	7%
		300	499	7.3	4%	4%	11%	8%
		500	1,049	14.1	6%	6%	14%	11%
Directional	R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	7.4	4%	0%	8%	4%
		473	524	8.3	4%	0%	8%	4%
		525	714	10.3	4%	1%	9%	4%
		715	937	13.8	5%	1%	9%	5%
		938	1,259	18.3	5%	1%	11%	5%
		1,260	1,399	22.2	6%	1%	11%	6%
		1,400	1,739	26.2	6%	1%	12%	6%
		1,740	2,174	32.6	6%	1%	12%	6%
		2,175	2,624	40.0	6%	1%	12%	6%
		2,625	2,999	46.9	6%	1%	12%	6%
		3,000	4,500	62.5	7%	1%	14%	7%
	*R, BR, and ER with medium screw bases w/ diameter ≤2.25"	400	449	7.1	4%	0%	7%	4%
		450	499	7.9	4%	0%	7%	4%
		500	649	9.6	4%	0%	8%	4%
		650	1,199	15.4	5%	1%	10%	5%
	*ER30, BR30, BR40, or ER40	400	449	7.1	4%	0%	7%	4%
		450	499	7.9	4%	0%	7%	4%

[740] Baseline post 2025 watts are calculated using the midpoint of the lumen range and an assumed efficacy of 70 lumens/watt for A-lamps, 60 lumens/watt for directional and 55 lumens/watt for decorative/globe. With the rapid decline in CFL sales and increase in LEDs, these efficacies are an estimated mix of CFL and non-ENERGY STAR LED.

	Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase after EISA 2025[740]	%Adj in 2025 ESTAR		%Adj in 2025 CEE T2	
					CRI <90	CRI >=90	CRI <90	CRI >=90
		500	649	9.6	4%	0%	8%	4%
	*BR30, BR40, or ER40	650	1,419	17.2	6%	1%	12%	6%
	*R20	400	449	7.1	4%	0%	7%	4%
		450	719	9.7	5%	1%	9%	5%
	*All reflector lamps below lumen ranges specified above	200	299	4.2	4%	1%	9%	4%
		300	399	5.8	4%	0%	8%	4%
EISA Non-Exempt	Dimmable Twist, Globe (<5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	250	309	4.0	3%	0%	6%	3%
		310	749	7.6	5%	0%	10%	5%
		750	1049	12.9	6%	0%	12%	6%
		1050	1489	18.1	8%	0%	15%	8%
		1490	2600	29.2	10%	0%	19%	10%

For example, for a 5W LED lamp, 200 lumens, 85 CRI decorative LED bulb purchased through retail in 2020:

ΔkWh = ((20.8 – 5) /1000) * 0.90 * 1,020 * (0.93 + (1.11 – 1))

= 15.1 kWh

This value should be claimed for five years, but from 2025 until the end of the measure life for that same lamp, savings should be reduced to (15.1 * 0.04 =) 0.60 kWh for the remainder of the measure life. Note these adjustments should be applied to kW and fuel impacts as well.

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * ISR * WHFdCool * CF$$

Where:

WHFdCool = Waste Heat Factor for demand to account for cooling savings from efficient lighting.

Bulb Location	WHFdCool
Building with cooling	1.22[741]
Building without cooling or exterior	1.0
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1.19[742]

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF
Residential Interior and in-unit Multifamily [743]	13.1%
Exterior [744]	1.8%
Unknown (e.g., Retail, Upstream,	11.4%

[741] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour) consistent with the lighting peak hours.

[742] The value is estimated at 1.19 (calculated as 1 + (0.88 * 0.61 / 2.8)).

[743] Based on analysis of loadshape data provided by Cadmus.

[744] Based on Itron eShapes lighting loadprofiles.

Bulb Location	CF
and Efficiency Kits)[745]	

Other factors as defined above

> **For example**, for a 5W LED lamp, 200 lumens, decorative LED bulb purchased through retail in 2020:
>
> ΔkW = ((20.8 – 5) /1000) * 0.90 * 1.19 * 0.114
>
> = 0.0019 kW

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes[746]:

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

Where:

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

= 53%[747] for interior or unknown location

= 0% for exterior or unheated location

0.03412 =Converts kWh to Therms

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

=74%[748]

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83%[749]

745 Assumes 15% exterior lighting, based on IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.

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

747 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.

748 This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

749 Based on Dunsky and Opinion Dynamics Baseline Study results

For example, for a 5W LED lamp, 200 lumens, decorative LED bulb purchased through retail in 2020:

ΔTherms = - ((((20.8 - 5) / 1000) * 0.90 * 1,020 * 0.53 * 0.03412) / 0.74) * 0.83

= - 0.29 therms

PEAK GAS SAVINGS

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[750]

For example, for a 5W LED lamp, 200 lumens, decorative LED bulb purchased through retail in 2020:

ΔPeakTherms = - 0.29 /217

= -0.0014 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

In order to account for the shift in baseline, an annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. Bulb replacement costs assumed in the O&M calculations are provided below[751].

Lamp Type	CRI	Product Type	Cost
Directional	<90	Inc/Hal	$5.00
		CFL	$6.00
		LED	$7.80
	>=90	Inc/Hal	$5.00
		CFL	$6.00
		LED	$7.63
Decorative	<90	Inc/Hal	$3.00
		CFL	$4.00
		LED	$7.50
	>=90	Inc/Hal	$3.00
		CFL	$4.00
		LED	$8.69

[750] Number of days where HDD 60 >0.

[751] Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017 and equivalent baseline bulbs.

The present value of replacement lamps and annual levelized replacement costs using the statewide real discount rate of 7.20% are presented below[752]:

			PV of replacement costs for period			Levelized annual replacement cost savings		
Lamp Type	CRI	Location	2020 Installs	2021 Installs	2022 Installs	2020 Installs	2021 Installs	2022 Installs
Directional	<90	Residential and in-unit Multifamily	$16.22	$13.65	$10.91	$2.33	$1.96	$1.57
		Exterior	$34.47	$29.17	$23.49	$4.95	$4.19	$3.37
		Unknown	$16.22	$13.65	$10.91	$2.33	$1.96	$1.57
	>=90	Residential and in-unit Multifamily	$16.17	$13.61	$10.86	$2.32	$1.96	$1.56
		Exterior	$34.43	$29.12	$23.44	$4.95	$4.19	$3.37
		Unknown	$16.17	$13.61	$10.86	$2.32	$1.96	$1.56
Decorative	<90	Residential and in-unit Multifamily	$10.58	$9.10	$7.52	$1.52	$1.31	$1.08
		Exterior	$20.65	$15.24	$12.75	$2.97	$2.19	$1.83
		Unknown	$10.58	$9.10	$7.52	$1.52	$1.31	$1.08
	>=90	Residential and in-unit Multifamily	$10.89	$9.44	$7.88	$1.57	$1.36	$1.13
		Exterior	$20.96	$15.58	$13.12	$3.01	$2.24	$1.88
		Unknown	$10.89	$9.44	$7.88	$1.57	$1.36	$1.13

Note: incandescent lamps in lumen range <310 and >3300 remain exempt from EISA. For these bulb types, an O&M cost should be applied as follows:

	Installation Location	Replacement Period (years)[753]	Replacement Cost
Directional	Residential Interior and in-unit Multifamily	5.7	$5.38
	Exterior	1.7	
	Unknown (e.g., Retail, Upstream, and Efficiency Kits)	4.2	
Decorative	Residential Interior and in-unit Multifamily	4.8	$3.55
	Exterior	1.5	
	Unknown (e.g., Retail, Upstream, and Efficiency Kits)	3.6	

[752] See "2019 LED Measure Cost and O&M Calc.xlsx " for more information.

[753] 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). Assumed lifetime of CFL is 10,000 and of LED Directional is 25,128 hours. and LED Decorative is 18,719 hours. Values provided are an average based on 80% incandescent/halogen, 10% CFL and 10% LED (blended average of 4,313 hours for directional and 3,672 for decorative bulbs).

MEASURE CODE: RS-LTG-LEDS-V04-200101

SUNSET DATE: 1/1/2021

2.5.5 LED Exit Signs

Description

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of an existing fluorescent/compact fluorescent (CFL) or incandescent exit sign in a Multifamily building. LED exit signs use a lower wattage of power (≤ 5 Watts) and have a significantly longer life compared to standard signs that can use up to 40 watts[754]. This in addition to reduced maintenance needs, and characteristic low-temperature light quality makes LED exit signs a superior option compared to other exit sign technologies available today.

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

Definition of Efficient Equipment

The efficient equipment is assumed to be an exit sign illuminated by LEDs with an input power demand of 5 watts or less per face.[755]

Definition of Baseline Equipment

The baseline is the existing system (either a CFL or incandescent unit)

Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 13 years[756].

Deemed Measure Cost

The actual material and labor costs should be used if available. If actual costs are unavailable, assume a total installed cost of $49.[757]

Loadshape

Loadshape E01 – Flat

Algorithm

Calculation of Savings

Electric Energy Savings [758]

$$\Delta kWh = \left(\frac{Watts_{\mathrm{bBase}} - Watts_{\mathrm{EE}}}{1000}\right) * Hours * (WHFeHeat + (WHFeCool - 1)$$

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following:

[754] ENERGY STAR "*Save Energy, Money and Prevent Pollution with LED Exit Signs*"
[755] ENERGY STAR "*Program Requirements for Exit Signs – Eligibility Criteria*" Version.3. While the EPA suspended the ENERGY STAR Exit Sign specification effective May 1, 2008, Federal requirements specify minimum efficiency standards for electrically-powered, single-faced exit signs with integral lighting sources that are equivalent to ENERGY STAR levels for input power demand of 5 watts or less per face.
[756] GDA Associates Inc. "Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures", June 2007.
[757] Price includes new exit sign/fixture and installation. EPA ENERGY STAR Exit Sign Calculator estimates LED cost/unit is $39 and assuming IA labor cost of 15 minutes @ $40/hr.
[758] There is no ISR calculation. Exit signs and emergency lighting are required by federal regulations to be installed and functional in all public buildings as outlined by the U.S. Occupational Safety and Health Standards (USOSHA 1993).

Project Type	Baseline Type	$Watts_{Base}$
Retrofit/Direct Install[759]	Incandescent (dual sided)	40W[760]
	Incandescent (single sided)	20W
	CFL (dual sided)	14W[761]
	CFL (single sided)	7W

$Watts_{EE}$ = Actual wattage if known, if unknown assume singled sided 2W and dual sided 4W[762]

Hours = Annual operating hours

= 8766

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section).

= 1 - ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.93[763]

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

= 53%[764] for interior or unknown location

= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment

= Actual system efficiency including duct loss – If not available, use[765]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 – 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.27[766]

[759] If program type does not know baseline assume the ratio of present incandescent to fluorescent exit sign units to be a deemed a weighted baseline of 70% incandescent to 30% CFL = 32.2W. This ratio has been used by ComEd and is reflective of program experience. In lieu of IA specific market research, we consider this evaluation to be reasonable.

[760]. Average incandescent watts are assumed at 40W as listed by the U.S. Department of Energy, ENERGY STARY Life Cycle Cost Exit-Sign Calculator available at https://www.energystar.gov/index.cfm?c=exit_signs.pr_exit_signs.

[761] Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

[762] Average Exit LED watts are assumed as a 2W as listed in Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

[762] Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

[763] Calculated using defaults; 1-((0.53/1.27) * 0.17) = 0.93

[764] This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, and Mason City and Burlington.

[765] 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.

[766] Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	17%[767]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting.

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12[768]
Building without cooling or exterior	1.0
Unknown	1.11[769]

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

ΔkWh = ((14 – 4) /1000) * 8,766 * (0.58 + (1.12 – 1)

= 61.4 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS[770]

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1{,}000} * WHFdCool * CF$$

Where:

$WHFd_{Cool}$ = Waste Heat Factor for demand to account for cooling savings from efficient lighting

Bulb Location	WHFdCool
Building with cooling	1.22[771]
Building without cooling or exterior	1.0
Unknown	1.19[772]

CF = Summer peak Coincidence Factor for this measure

Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.

[767] Based on Dunsky and Opinion Dynamics Baseline Study results.

[768] The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). Based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Des Moines, and Mason City and Burlington), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * 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).

[769] The value is estimated at 1.11 (calculated as 1 + (0.88*(0.34 / 2.8)). Based on assumption that 88% of homes have central cooling (based on Dunsky and Opinion Dynamics Baseline Study results).

[770] There is no ISR calculation. Exit signs and emergency lighting are required by federal regulations to be installed and functional in all public buildings as outlined by the U.S. Occupational Safety and Health Standards (USOSHA 1993).

[771] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour) consistent with the lighting peak hours.

[772] The value is estimated at 1.19 (calculated as 1 + (0.88 * 0.61 / 2.8)).

= 1.0[773]

> **For example**, for a 4W, dual sided LED exit sign replacing a CFL lamp in a building with cooling:
>
> ΔkW = ((14 – 4) /1000) * 1.22 * 1.0
>
> = 0.0122 kW

NATURAL GAS ENERGY SAVINGS

Heating Penalty for Natural Gas heated homes[774]:

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

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 53%[775] for interior or unknown location

= 0% for exterior or unheated location

0.03412 = Converts kWh to Therms

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

= 74%[776]

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83%[777]

> **For example**, for a 4W, dual sided LED exit sign replacing a CFL lamp in gas heated building:
>
> ΔTherms = - ((((14 – 4) /1000) * 8,766 * 0.53 * 0.03412)/0.74) * 1.0
>
> = - 2.1 therms

PEAK GAS SAVINGS

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings

773 773 Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

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

775 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.

776 This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

777 Based on Dunsky and Opinion Dynamics Baseline Study results.

is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[778]

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in gas heated building:

ΔPeakTherms = -2.1/217

= -0.0097 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.

Program Type	Component	Baseline Measure	
		Cost	Life (yrs)
Retrofit/Direct Install779	CFL lamp	$13.00780	0.57 years781
	Incandescent lamp	$11.27782	0.17 years783

MEASURE CODE: RS-LTG-EXIT-V02-180101

SUNSET DATE: 1/1/2023

[778] Number of days where HDD 60 >0.
[779] If program component is unknown use 70/30 split for costs and life = $11.87 and 0.29 yrs
[780] Consistent with assumption as listed by the U.S. Department of Energy, ENERGY STARY Life Cycle Cost Exit-Sign Calculator available at https://www.energystar.gov/index.cfm?c=exit_signs.pr_exit_signs for estimated labor cost of $10 (assuming $40/hour and a task time of 15 minutes). Replacement of a CFL bulb is assumed to be $3 as noted by regional IA program details (IPL Business Assessment).
[781] ENERGY STAR "*Save Energy, Money and Prevent Pollution with LED Exit Signs*" specifies that CFL bulbs for Exit Signs typically have an average rated life of 5000-6000 hours. Given 24/7 run time assume Exit Light replacement requirements as 5,500/8760.
[782] Assume incandescent A-lamp 45W is $1.27 per Itron, Ex Ante Measure cost Study, 2014 "WA017_MCS Results Matrix - Volume I (1).xlsx"
[783] ENERGY STAR "*Save Energy, Money and Prevent Pollution with LED Exit Signs*" specifies that a typical incandescent exit sign bulb will be approx. 40W and will have a rated life of 500-2000 hours. Given 24/7 run time of the Exit Sign the replacement requirements would be an average of 1500/8766.

2.5.6 LED Fixtures

Description

This characterization provides savings assumptions for LED Fixtures and is broken into four ENERGY STAR fixture types: Indoor Fixtures (including track lighting, wall-wash, sconces, ceiling and fan lights), Task and Under Cabinet Fixtures, Outdoor Fixtures (including flood light, hanging lights, security/path lights, outdoor porch lights), and Downlight Fixtures. For upstream programs, utilities should develop an assumption of the Residential v Nonresidential split and apply the relevant assumptions to each portion.

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) requires all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than standard incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W lamps in 2013 and 60W and 40W lamps in 2014. The baseline for this measure has therefore become fixtures with bulbs (improved incandescent or halogen) that meet the new standard. Furthermore, the Technical Advisory Committee approved assuming a blended baseline condition of EISA qualified incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt. However, the Iowa TAC agreed to delay this baseline shift to January 1, 2021.[784]

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

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

Definition of Efficient Equipment

In order for this characterization to apply, new fixtures must be ENERGY STAR labeled based upon the v2.1 ENERGY STAR specification for luminaires (https://www.energystar.gov/sites/default/files/Luminaires%20V2.1%20Spec%20Final%20with%20Partner%20Commitments.pdf). Specifications are as follows:

Fixture Category	Lumens/Watt
Indoor	65
Task and Under Cabinet	50
Outdoor	60
Downlight	55

Definition of Baseline Equipment

The baseline condition for this measure is assumed to be an average of EISA-equivalent wattages for ENERGY STAR-qualified products. From 2021 the baseline lumens/watt is assumed to increase depending on fixture type (see table below)[785] and therefore a midlife adjustment is provided.

[784] The Iowa TAC agreed to delay the EISA baseline shift to 2021 to account for customers purchasing final halogen bulbs shortly before the 2020 provision comes in to effect, potentially stockpiling, an apparent lack of enforcement, political uncertainty, and experience with other standard changes where supposedly non-conforming product has remained readily available for a number of years.

[785] 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 for lamps equivalent to a current day CFL. However, with the rapid decline in CFL sales and increase in LEDs, 70 lumens per watt is assumed for lamps based on an estimated mix of CFL and non-ENERGY STAR LED. 2021 lumens/watt for fixtures is calculated by multiplying the assumed 2021 baseline efficacy for lamps in 2021 (70 lu/watt) by the ratio of the ENERGY STAR efficacy requirement for fixtures to the ENERGY STAR v.2.1 efficacy requirement for omnidirectional lamps with a CRI <90 (80 lu/watt). See file Residential LED Fixtures_Analysis_Apr 2018.xlsx for calculations.

Fixture Category	2021 Lumens/Watt
LED ENERGY STAR Indoor Fixture	57
LED ENERGY STAR Task /Under Cabinet Fixture	44
LED ENERGY STAR Outdoor Fixture	53
LED ENERGY STAR Downlight Fixture	48

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of a fixture is a function of its rated life and average hours of use. The rated life is 47,000 hours for indoor and downlight, 45,000 for task and cabinet, and 49,000 for outdoor fixtures[786]. This would imply a lifetime of 51 years for indoor and downlight, 62 years for task and under cabinet, and 20 years for outdoor fixtures. However, all installations are capped at 15 years[787] so a 15 year measure life should be assumed.

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:

Fixture Category	Incremental Cost
Indoor	$26[788]
Task /Under Cabinet	$18[789]
Outdoor	$26
Downlight	$13

LOADSHAPE

Loadshape RE09 – Residential Indoor Lighting

Loadshape RE10 – Residential Outdoor Lighting

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

$Watts_{Base}$ = Baseline is an average of lumen-equivalent EISA wattages for ENERGY STAR products within the fixture category;[790] see table below

$Watts_{EE}$ = Actual wattage of LED fixture purchased / installed – If unknown, use default provided below[791]

[786] Average rated lives are based on the average rated lives of fixtures available on the ENERGY STAR qualifying list as of 2/26/2018.

[787] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

[788] Incremental costs for indoor and outdoor fixtures based on ENERGY STAR Light Fixtures and Ceiling Fans Calculator, which cites “EPA research on available products, 2012.” ENERGY STAR cost assumptions were reduced by 20% to account for falling LED prices.

[789] Incremental costs for task/under cabinet and downlight fixtures are from the 2018 Michigan Energy Measures Database.

[790] See “Analysis” tab within file Residential LED Fixtures_Analysis_Apr 2018.xlsx for baseline calculations.

[791] Average of ENERGY STAR product category watts for products at or above the version 2.1 efficacy specification

Fixture Category	$Watts_{Base}$	$Watts_{EE}$
Indoor	88.5	22.4
Task /Under Cabinet	45.2	11.6
Outdoor	79.6	18.3
Downlight	72.8	20.3

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

= 1.0[792]

Hours = Average hours of use per year

Fixture Category	Hours
Residential and Downlight	926[793]
Task/Under Cabinet	730[794]
Outdoor	2,475[795]

$WHFe_{Heat}$ = Waste Heat Factor for energy to account for electric heating increase from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section).

= 1 - ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.93[796]

Where:

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

= 53%[797] for interior

= 0% for exterior or unheated location

$ηHeat_{Electric}$ = Efficiency in COP of Heating equipment

= Actual system efficiency including duct loss – If not available, use[798]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 – 2014	7.7	1.92

792 ISR recommendation for fixtures in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-22.

793 Assuming 365.25 days/year and average of recommended values for standard LED lamps (1088) and specialty LED lamps (763) in interior locations from Opinion Dynamics "Illinois Statewide Residential LED Hours of Use Study Additional Results," April 17, 2018.

794 Task/under cabinet hours of use are estimated at 2 hours per day.

795 Based on secondary research conducted as part of the Illinois PY5/PY6 ComEd Residential Lighting Program evaluation.

796 Calculated using defaults; 1-((0.53/1.27) * 0.17) = 0.93.

797 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.

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

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
	2015 on	8.2	2.04
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.27[799]

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	17%[800]

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting.

Fixture Location	$WHFe_{Cool}$
Building with cooling	1.12[801]
Building without cooling or exterior	1.0
Unknown	1.11[802]

Mid-Life Baseline Adjustment

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Under the EISA backstop provision, the baseline bulb changes to a CFL equivalent in 2020 (except for <310 and 3300+ lumen lamps). However, the Iowa TAC agreed to delay this baseline shift to 2021.[803] The annual savings claim must be reduced within the life of the measure to account for this baseline shift. This reduced annual savings will need to be incorporated in to cost effectiveness screening calculations. The baseline adjustment also impacts the O&M schedule.

For example, for an indoor LED fixture installed in 2019, the full savings (as calculated above in the Algorithm) should be claimed for the first two 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.

---

799 Calculation assumes 33% Heat Pump and 67% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls". Average efficiency of heat pump is based on the assumption that 50% are units from before 2006 and 50% 2006-2014.

800 Based on Dunsky and Opinion Dynamics Baseline Study results.

801 The value is estimated at 1.12 (calculated as 1 + (0.34 / 2.8)). Based on cooling loads decreasing by 34% of the lighting savings (average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm $(-0.02 * SEER^2) + (1.12 * SEER)$ (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

802 The value is estimated at 1.11 (calculated as 1 + (0.88*(0.34 / 2.8)). Based on assumption that 88% of homes have central cooling (based on Dunsky and Opinion Dynamics Baseline Study results).

803 The Iowa TAC agreed to delay the EISA baseline shift to 2021 to account for sell through of remaining product, apparent lack of enforcement, political uncertainty, and experience with other standard changes where supposedly non-conforming product has remained readily available for a number of years.

Fixture Category	2020 Lumens/Watt[804]	WattsBase after EISA 2020[805]	%Adj in 2021
Indoor	57	42.2	30%
Task /Under Cabinet	44	22.2	32%
Outdoor	53	39.6	35%
Downlight	48	39.9	37%

For example, an indoor LED fixture is purchased through retail in 2019:

ΔkWh = ((88.5 – 22.4) /1000) * 1.0 * 926 * (0.93 + (1.11 – 1))

= 63.7 kWh

This value should be claimed for two years, but from 2021 until the end of the measure life for that same fixture, savings should be reduced to (63.7 * 0.30) = 19.1 kWh for the remainder of the measure life. Note these adjustments should be applied to kW and fuel impacts as well.

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * WHFdCool * CF$$

Where:

WHFdCool = Waste Heat Factor for demand to account for cooling savings from efficient lighting.

Fixture Location	WHFdCool
Building with cooling	1.22[806]
Building without cooling or exterior	1.0
Unknown (e.g. Retail and Upstream)	1.19[807]

CF = Summer peak Coincidence Factor for measure.

Fixture Location	CF
Residential Interior and in-unit Multifamily [808]	13.1%
Exterior [809]	1.8%

Other factors as defined above

[804] 2020 lumens/watt for fixtures is calculated by multiplying the assumed 2020 baseline efficacy for lamps (70 lu/watt) by the ratio of the ENERGY STAR efficacy requirement for fixtures to the ENERGY STAR v.2.1 efficacy requirement for omnidirectional lamps with a CRI <90 (80 lu/watt). See file Residential LED Fixtures_Analysis_Apr 2018.xlsx for calculations.

[805] Baseline post 2020 watts are calculated using the 2020 lumens/watt value for each fixture category.

[806] The value is estimated at 1.22 (calculated as 1 + (0.61 / 2.8)). See footnote relating to WHFe for details. Note the 61% factor represents the Residential cooling coincidence factor calculated using the average load during the peak period (as opposed to the peak hour) consistent with the lighting peak hours.

[807] The value is estimated at 1.19 (calculated as 1 + (0.88 * 0.61 / 2.8)).

[808] Based on analysis of loadshape data provided by Cadmus.

[809] Based on Itron eShapes lighting loadprofiles.

> **For example,** for an indoor LED fixture purchased through retail in 2019:
>
> ΔkW = ((88.5 – 22.4) /1000) * 1.0 * 1.19 * 0.131
>
> = 0.0103 kW

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes[810]:

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

Where:

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

= 53%[811] for interior

= 0% for exterior or unheated location

0.03412 =Converts kWh to Therms

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

=74%[812]

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83%[813]

> **For example**, for an indoor LED fixture purchased through retail in 2019:
>
> ΔTherms = - ((((88.5 – 22.4) / 1000) * 1.0 * 926 * 0.53 * 0.03412) / 0.74) * 0.83
>
> = - 1.24 therms

PEAK GAS SAVINGS

For ease of application, savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

---

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

811 This means that heating loads increase by 53% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Des Moines, Mason City, and Burlington, IA.

812 This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

813 Based on Dunsky and Opinion Dynamics Baseline Study results

$$\Delta PeakTherms = \frac{\Delta Therms}{HeatDays}$$

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 217[814]

For example, for an indoor LED fixture purchased through retail in 2019:

ΔPeakTherms = - 1.24 /217

= -0.0057 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

In order to account for the shift in baseline due to the backstop provision of the Energy Independence and Security Act of 2007, requiring all standard bulbs (except for <310 and 3300+ lumen lamps) to have an efficacy equivalent to today's CFL, an annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. Bulb replacement costs assumed in the O&M calculations are provided below[815].

Product Type	Cost
Inc/Hal	$1.40
CFL	$1.82
LED	$3.42

The present value of replacement lamps and annual levelized replacement costs using the statewide real discount rate of 7.20% are presented below[816]:

Fixture Type	PV of replacement costs for period		Levelized annual replacement cost savings	
	2020 Installs	2021 Installs	2020 Installs	2021 Installs
Indoor	$1.60	$0.42	$0.23	$0.06
Task /Under Cabinet	$1.77	$0.34	$0.25	$0.05
Outdoor	$5.12	$3.24	$0.74	$0.47
Downlight	$1.60	$0.42	$0.23	$0.06

MEASURE CODE: RS-LTG-LDFX-V02-200101

SUNSET DATE: 1/1/2021

814 Number of days where HDD 60 >0.

815 Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017 and equivalent baseline bulbs. CFL and LED lamp costs are an average of costs for lamps with a CRI of <90 and >=90.

816 See "Residential LED Fixtures_Analysis_2019.xlsx" for more information.

2.6 Shell

2.6.1 Infiltration Control

Description

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. An estimate of savings is provided in two ways. It is highly recommended that leaks be detected and pre- and post-sealing leakage rates measured with the assistance of a blower-door by qualified/certified inspectors[817]. Where this occurs, an algorithm is provided to estimate the site specific savings. Where test in/test out has not occurred, a conservative deemed assumption is provided.

If sealing of ducts is unknown, the sealed efficiency should be used.

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

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

Definition of Efficient Equipment

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be assessed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

Definition of Baseline Equipment

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly affects the opportunity for cost-effective energy savings through air sealing.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[818]

Deemed Measure Cost

The actual capital cost for this measure should be used.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

[817] Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.

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

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Test In / Test Out Approach

$$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

$$= \frac{\left(\frac{CFM50_{Pre} - CFM50_{Post}}{N_{cool}}\right) * 60 * 24 * CDD * DUA * 0.018 * LM}{(1000 * \eta Cool)}$$

$CFM50_{Pre}$ = Infiltration at 50 Pascals as measured by blower door before air sealing

= Actual[819]

$CFM50_{Post}$ = Infiltration at 50 Pascals as measured by blower door after air sealing

= Actual

N_{cool} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

=Dependent on location and number of stories:[820]

Climate Zone (City based upon)	N_cool (by # of stories)			
	1	1.5	2	3
Zone 5 (Burlington)	37.0	32.8	30.1	26.6
Zone 6 (Mason City)	32.5	28.8	26.4	23.4
Average/ unknown (Des Moines)	34.3	30.4	27.9	24.7

60 * 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

= Dependent on location[821]:

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown (Des Moines)	1,068

[819] Because the pre- and post-sealing blower door test will occur on different days, there is a potential for the wind and temperature conditions on the two days to affect the readings. There are methodologies to account for these effects. For wind - first if possible, avoid testing in high wind, place blower door on downwind side, take a pre-test baseline house pressure reading and adjust your house pressure readings by subtracting the baseline reading, and use the time averaging feature on the digital gauge, etc. Corrections for air density due to temperature swings can be accounted for with Air Density Correction Factors. Refer to the Energy Conservatory Blower Door Manual for more information.

[820] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets on the SharePoint site.

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

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [822]

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[823]:

Age of Equipment	SEER Sealed Estimate	SEER Unsealed Estimate (SEER Sealed * 0.85)
Before 2006	10	8.5
2006 – 2014	13	11
Central AC After 1/1/2015	13	11
Heat Pump After 1/1/2015	14	12

LM = Latent multiplier to account for latent cooling demand

= dependent on location: [824]

Climate Zone (City based upon)	LM
Zone 5 (Burlington)	4.1
Zone 6 (Mason City)	4.2
Average/ unknown (Des Moines)	4.2

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \frac{\frac{(CFM50_{Pre} - CFM50_{Post})}{N\_heat} * 60 * 24 * HDD * 0.018}{(\eta Heat * 3{,}412)}$$

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on location and building height:[825]

[822] This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[823] 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.

[824] The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads. The values are derived from the methodology outlined in Infiltration Factor Calculation Methodology by Bruce Harley, Senior Manager, Applied Building Science, CLEAResult 11/18/2015 and is based upon an 8760 analysis of sensible and total heat loads using hourly climate data.

[825] 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

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
Zone 5 (Burlington)	23.5	20.8	19.1	16.9
Zone 6 (Mason City)	21.0	18.6	17.0	15.1
Average/ unknown (Des Moines)	22.2	19.7	18.0	16.0

HDD = Heating Degree Days

= Dependent on location:[826]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

ηHeat = Efficiency of heating system

= Actual – If not available refer to default table below[827]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

3412 = Converts Btu to kWh

information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets on the SharePoint site.

[826] 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.

[827] 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, for a 2 story single family home in Des Moines with 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), with pre- and post-sealing blower door test results of 3,400 and 2,250:

ΔkWh = ΔkWh_cooling + ΔkWh_heating

= [(((3,400 – 2,250) / 27.9) * 60 * 24 * 1068 * 0.75 * 0.018 * 6.2) / (1000 * 10.5)] + [(((3,400 – 2,250) / 18.0) * 60 * 24 * 5092 * 0.018) / (1.92 * 3,412)]

= 505.3 + 1287.2

= 1,792.5 kWh

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[828]

Building Type	HVAC System	SavingsPerUnit (kWh/ft)
Manufactured	Central Air Conditioner	0.062
Multifamily	Central Air Conditioner	0.043
Single Family	Central Air Conditioner	0.050
Manufactured	Electric Furnace/Resistance Space Heat	0.413
Multifamily	Electric Furnace/Resistance Space Heat	0.285
Single Family	Electric Furnace/Resistance Space Heat	0.308
Manufactured	Air Source Heat Pump	0.391
Multifamily	Air Source Heat Pump	0.251
Single Family	Air Source Heat Pump	0.308
Manufactured	Air Source Heat Pump – Cooling	0.062
Multifamily	Air Source Heat Pump – Cooling	0.043
Single Family	Air Source Heat Pump – Cooling	0.050
Manufactured	Air Source Heat Pump – Heating	0.329
Multifamily	Air Source Heat Pump – Heating	0.208
Single Family	Air Source Heat Pump – Heating	0.257

SqFt = Building conditioned square footage

= Actual

Additional Fan savings

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

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

= 3.14%[829]

[828] The values in the table represent estimates of savings from a 15% improvement in air leakage. The values are half those provided by Cadmus for the Joint Assessment, based on building simulations performed. While 30% savings are certainly achievable, this represents a thorough job in both the attic and basements and could not be verified without testing. The conservative 15% estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

[829] 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

> **For example,** for a 2 story single family home in Des Moines with a gas furnace with system efficiency of 70%, with pre- and post-sealing blower door test results of 3,400 and 2,250 (see therm calculation in Natural Gas Savings section):
>
> ΔkWh = 114 * 0.0314 * 29.3
>
> = 105 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh\_cooling}{FLH\_cooling} * CF$$

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[830]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home conditioning[831], 43.1%[832] for ductless HP used as supplemental or limited zone

> **For example**, for a 2 story single family home in Des Moines with 10.5 SEER central cooling and a heat pump with COP of 2.0, with pre- and post-sealing blower door test results of 3,400 and 2,250:
>
> ΔkW = 505.3 / 811 * 0.68
>
> = 0.42 kW

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

$$\Delta Therms = \frac{\frac{(CFM50_{Pre} - CFM50_{Post})}{N\_heat} * 60 * 24 * HDD * 0.018}{(\eta Heat * 100{,}000)}$$

Where:

calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Furnace Fan Analysis.xlsx" for reference.

830 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

831 Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

832 Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on location and building height:[833]

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
Zone 5 (Burlington)	23.5	20.8	19.1	16.9
Zone 6 (Mason City)	21.0	18.6	17.0	15.1
Average/ unknown (Des Moines)	22.2	19.7	18.0	16.0

HDD = Heating Degree Days

= Dependent on location:[834]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[835] – If not available, use 74%[836] for unsealed ducts or 87% for sealed ducts

Other factors as defined above

For example, for 2 story single family home in Des Moines with a gas furnace with system efficiency of 70%, with pre- and post-sealing blower door test results of 3,400 and 2,250:

ΔTherms = (((3,400 – 2,250)/18.0) * 60 * 24 * 5052 * 0.018) / (0.74 * 100,000)

= 113.1 therms

[833] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets on the SharePoint site.

[834] 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.

[835] 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.

[836] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

Conservative Deemed Approach

$$\Delta Therms = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[837]

Building Type	HVAC System	SavingsPerUnit (Therms/ft)
Manufactured	Gas Boiler	0.022
Multifamily	Gas Boiler	0.018
Single Family	Gas Boiler	0.016
Manufactured	Gas Furnace	0.017
Multifamily	Gas Furnace	0.012
Single Family	Gas Furnace	0.013

SqFt = Building square footage

= Actual

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[838]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, for a 2 story single family home in Chicago with a gas furnace with system efficiency of 70%, with pre- and post-sealing blower door test results of 3,400 and 2,250:

ΔPeakTherms = 113.1 * 0.016525

= 1.87 therms

Conservative Deemed Approach

Building Type	HVAC System	SavingsPerUnit (PeakTherms/ft)
Manufactured	Gas Boiler	0.000313
Multifamily	Gas Boiler	0.000259
Single Family	Gas Boiler	0.000237
Manufactured	Gas Furnace	0.000281
Multifamily	Gas Furnace	0.000191
Single Family	Gas Furnace	0.000220

837 The values in the table represent estimates of savings from a 15% improvement in air leakage. The values are half those provided by Cadmus for the Joint Assessment, based on building simulations performed. While 30% savings are certainly achievable, this represents a thorough job in both the attic and basements and could not be verified without testing. The conservative 15% estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

838 Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AIRS-V03-200101

SUNSET DATE: 1/1/2022

2.6.2 Attic/Ceiling Insulation

Description

This measure describes savings from adding insulation to the attic/ceiling. This measure requires a member of the implementation staff evaluating the pre- and post-project R-values and to measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible. If sealing of ducts is unknown, the sealed efficiency should be used.

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

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

Definition of Efficient Equipment

The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 25 years.[839]

Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) * A_{attic} * (1 - FramingFactor_{Attic}) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Attic} = R-value of new attic assembly including all layers between inside air and outside air

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

(ft^2.°F.h/Btu)

= Actual[840]

R_{Old} = R-value value of existing assembly and any existing insulation

(Minimum of R-5 for uninsulated assemblies[841])

A_{Attic} = Total area of insulated ceiling/attic (ft^2)

$FramingFactor_{Attic}$ = Adjustment to account for area of framing

= 7%[842]

CDD = Cooling Degree Days

= Dependent on location[843]:

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown (Des Moines)	1,068

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [844]

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:[845]

Age of Equipment	ηCool Sealed Duct Estimate	ηCool Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	10	8.5
2006 – 2014	13	11
Central AC after 1/1/2015	13	11

840 If open cavity, add new insulation value to the default or evaluated existing assembly R-value (R_{old}). If closed cavity, since you are displacing one or two air layers, reduce the default or evaluated existing assembly R-value by one and add to new insulation. Note, if existing insulation is added to/not removed – always re-evaluate R-value of existing insulation as it may have been degraded significantly due to compression etc.

841 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).

842 ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1

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

844 This factor's source: Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

845 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

Age of Equipment	ηCool Sealed Duct Estimate	ηCool Unsealed Duct Estimate (nCool Sealed * 0.85)
Heat Pump after 1/1/2015	14	12

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) * A_{Attic} * (1 - FramingFactor_{Attic}) * HDD * 24}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:[846]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

ηHeat = Efficiency of heating system

= Actual – If not available, refer to default table below:[847]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

3412 = Converts Btu to kWh

For example, for a single family home in Mason City with 700 ft^2 of R-5 attic insulated to R-49, 10.5 SEER Central AC, and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((1/5 - 1/49) * 700 * (1-0.07) * 616 * 24 * 0.75)/ (1000 * 10.5)) + (((1/5 - 1/49) * 700 * (1-0.07) * 6391 * 24) / (1.92 * 3412))

= 123 + 2737

= 2860 kWh

[846] 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.

[847] 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.

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

Where:

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

= 3.14%[848]

29.3 = kWh per therm

For example, for a single family home in Mason City with 700 ft^2 of R-5 attic insulated to R-49, with a gas furnace with system efficiency of 74% (for therm calculation see Natural Gas Savings section) with unsealed ducts:

ΔkWh = 179.2 * 0.0314 * 29.3

= 165 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh\_cooling}{FLH\_cooling} * CF$$

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[849]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home conditioning[850], 43.1%[851] for ductless HP used as supplemental or limited zone

For example, for a single family home in Mason City with 700 ft^2 of R-5 attic insulated to R-49, 10.5 SEER Central AC, and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkW = 123 / 468 * 0.68

= 0.1787 kW

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

[849] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

[850] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[851] Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

Natural Gas Savings

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{attic}}\right) * A_{Attic} * (1 - FramingFactor_{Attic}) * HDD * 24}{(\eta Heat * 100{,}000)}$$

Where:

HDD = Heating Degree Days

= Dependent on location:[852]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual.[853] If unknown assume 74%[854] for unsealed ducts or 87% for sealed ducts..

100,000 = Converts Btu to Therms

Other factors as defined above

For example, for a single family home in Mason City with 700 ft^2 of R-5 attic insulated to R-49, with a gas furnace with system efficiency of 87% with sealed ducts:

ΔTherms = ((1/5 - 1/49) * 700 * (1-0.07) * 6391 * 24) / (0.87 * 100,000)

= 206.1therms

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

[852] 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.

[853] 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.

[854] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

GCF = Gas Coincidence Factor for Heating[855]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, for a single family home in Mason City with 700 ft^2 of R-5 attic insulated to R-49, with a gas furnace with system efficiency of 87% with sealed ducts:

ΔPeakTherms = 206.1* 0.016525

= 3.406therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AINS-V04-200101

SUNSET DATE: 1/1/2022

[855] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.6.3 Rim/Band Joist Insulation

Description

This measure describes savings from adding insulation (either rigid or spray foam) to rim/band joist cavities. This measure requires a member of the implementation staff evaluating the pre- and post-project R-values and to measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

Note unconditioned means a space that is not intentionally heated via furnace vents or boiler radiators. The presence of and/or leakage from a heating system in a space doesn't in itself imply the space is conditioned. If sealing of ducts is unknown, the sealed efficiency should be used.

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

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

Definition of Efficient Equipment

The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be an uninsulated rim/band joist.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 25 years.[856]

Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

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

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Rim} = R-value of new rim/band joist assembly including all layers between inside air and outside air (ft^2.°F.h/Btu)

= Actual[857]

R_{old} = R-value value of existing assembly and any existing insulation (ft^2.°F.h/Btu).

(Minimum of R-5 for uninsulated assemblies[858])

A_{Rim} = Net area of insulated rim/band joist (ft^2)

$FramingFactor_{Rim}$ = Adjustment to account for area of framing

= 25%[859]

CDD = Cooling Degree Days

= Dependent on location and whether in conditioned or unconditioned space:

Climate Zone (City based upon)	Conditioned Space CDD 65 [860]	Unconditioned Space CDD 75 [861]
Zone 5 (Burlington)	1,209	411
Zone 6 (Mason City)	616	264
Average/ unknown (Des Moines)	1,068	474

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [862]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

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857 If open cavity, add new insulation value to the default or evaluated existing assembly R-value (R_{old}). If closed cavity, since you are displacing one or two air layers, reduce the default or evaluated existing assembly R-value by one and add to new insulation. Note, if existing insulation is added to/not removed – always re-evaluate R-value of existing insulation as it may have been degraded significantly due to compression etc.

858 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).

859 Consistent with Wall framing factor assumption; ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.

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

861 The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. Five year average cooling degree days with 75F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72F.

862 This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

= Actual (where it is possible to measure or reasonably estimate) – If unknown, assume the following:[863]

Age of Equipment	ηCool Sealed Duct Estimate	ηCool Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	10	8.5
2006 – 2014	13	11
Central AC after 1/1/2015	13	11
Heat Pump after 1/1/2015	14	12

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJRim}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

= Dependent on location and whether in conditioned or unconditioned space:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space
	HDD 60 [864]	HDD 50 [865]
Zone 5 (Burlington)	4,496	2,678
Zone 6 (Mason City)	6,391	4,222
Average/ unknown (Des Moines)	5,052	3,126

ηHeat = Efficiency of heating system

= Actual – If not available, refer to default table below:[866]

[863] 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.

[864] 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.

[865] The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

[866] 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) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 on	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

3412 = Converts Btu to kWh

ADJ_{Rim} = Adjustment for rim/band joist insulation to account for prescriptive engineering algorithms consistently overclaiming savings.

=63%[867]

For example, for a single family home in Mason City with 100 ft^2 of uninsulated (assume R-5) rim/band joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((1/5 - 1/13) * 100 * (1-0.25) * 264 * 24 * 0.75) / (1000 * 10.5)) + (((1/5 - 1/13) * 100 * (1-0.25) * 4222 * 24 * 0.63) / (1.92 * 3412))

= 4.2 + 89.9

= 94.1 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

Where:

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

= 3.14%[868]

29.3 = kWh per therm

For example, for a single family home in Mason City with 100 ft^2 of uninsulated (assume R-5) rim/band joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 74% (for therm calculation see Natural Gas Savings section) with unsealed ducts:

ΔkWh = 8.0 * 0.0314 * 29.3

= 7.4 kWh

[867] Consistent with ADJWall; Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation", August 2012. See "Insulation ADJ calculations.xls" for details or calculation.

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

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh\_cooling}{FLH\_cooling} * CF$$

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[869]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home conditioning[870], 43.1%[871] for ductless HP used as supplemental or limited zone

For example, for a single family home in Mason City with 100 ft^2 of uninsulated (assume R-5) rim/band joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkW = 4.2 / 468 * 0.68

= 0.0061 kW

Natural Gas Savings

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJRim}{(\eta Heat * 100{,}000)}$$

Where:

HDD = Heating Degree Days

= Dependent on location and whether in conditioned or unconditioned space:

[869] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

[870] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[871] Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

Climate Zone (City based upon)	Conditioned Space HDD 60 [872]	Unconditioned Space HDD 50 [873]
Zone 5 (Burlington)	4,496	2,678
Zone 6 (Mason City)	6,391	4,222
Average/ unknown (Des Moines)	5,052	3,126

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual.[874] If unknown assume 87%for unsealed ducts of 74%[875] for sealed ducts

100,000 = Converts Btu to Therms

Other factors as defined above

For example, for a single family home in Mason City with 100 ft^2 of uninsulated (assume R-5) rim/band joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 87% with sealed ducts:

ΔTherms = ((1/5 - 1/13) * 100 * (1-0.25) * 4222 * 24 * 0.63) / (0.87 * 100,000)

= 6.8therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[876]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

[872] 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.

[873] The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

[874] 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.

[875] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

[876] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

For example, for a single family home in Mason City with 100 ft^2 of uninsulated (assume R-5) rim/band joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 87% with sealed ducts:

ΔPeakTherms = 6.8* 0.016525

= 0.11therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-RINS-V03-200101

SUNSET DATE: 1/1/2022

2.6.4 Wall Insulation

Description

This measure describes savings from adding insulation (for example, blown cellulose, spray foam) to wall cavities. This measure requires a member of the implementation staff evaluating the pre- and post-project R-values and to measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible. If sealing of ducts is unknown, the sealed efficiency should be used.

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

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

Definition of Efficient Equipment

The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 25 years.[877]

Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Savings

Electric Energy Savings

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Wall}}\right) * A_{Wall} * (1 - FramingFactor_{Wall}) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Wall} = R-value of new wall assembly including all layers between inside air and outside air

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

(ft^2.°F.h/Btu)

R_{Old} = R-value value of existing assembly and any existing insulation (ft^2.°F.h/Btu)

(Minimum of R-5 for uninsulated assemblies[878])

A_{Wall} = Net area of insulated wall (ft^2)

$FramingFactor_{Wall}$ = Adjustment to account for area of framing

= 25%[879]

CDD = Cooling Degree Days

= Dependent on location[880]:

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown (Des Moines)	1,068

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [881]

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:[882]

Age of Equipment	ηCool Sealed Duct Estimate	ηCool Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	10	8.5
2006 – 2014	13	11
Central AC after 1/1/2015	13	11
Heat Pump after 1/1/2015	14	12

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

[878] 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).

[879] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.

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

[881] 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.

[882] 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.

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Wall}}\right) * A_{wall} * (1 - FramingFactor_{Wall}) * HDD * 24 * ADJWall}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:[883]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

ηHeat = Efficiency of heating system

= Actual – If not available, refer to default table below:[884]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

3412 = Converts Btu to kWh

ADJ_{Wall} = Adjustment for wall insulation to account for prescriptive engineering algorithms consistently overclaiming savings

= 63%[885]

For example, for a single family home in Mason City with 990 ft² of R-5 walls insulated to R-13, 10.5 SEER Central AC, and 2.26 (1.92 including distribution losses) COP Heat Pump with sealed ducts:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((1/5 - 1/13) * 990 * (1-0.25) * 616 * 24 * 0.75) / (1000 * 10.5)) + (((1/5 - 1/13) * 990 * (1-0.25) * 6391 * 24 * 0.63) / (1.92 * 3412))

= 97 + 1348

= 1445 kWh

[883] 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.

[884] 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.

[885] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation", August 2012. See "Insulation ADJ calculations.xls" for details or calculation.

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

Where:

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

= 3.14%[886]

29.3 = kWh per therm

For example, for a single family home in Mason City with 990 ft^2 of R-5 walls insulated to R-13, with a gas furnace with system efficiency of 74% (for therm calculation see Natural Gas Savings section) with sealed ducts:

ΔkWh = 119.3 * 0.0314 * 29.3

= 110 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh\_cooling}{FLH\_cooling} * CF$$

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[887]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home conditioning[888], 43.1%[889] for ductless HP used as supplemental or limited zone

For example, for a single family home in Mason City with 990 ft^2 of R-5 walls insulated to R-13, 10.5 SEER Central AC, and 2.26 (1.92 including distribution losses) COP Heat Pump with sealed ducts:

ΔkW = 97 / 468 * 0.68

= 0.1409 kW

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

887 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

888 Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

889 Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{wall}}\right) * A_{wall} * (1 - FramingFactor_{Wall}) * HDD * 24 * ADJWall}{(\eta Heat * 100{,}000)}$$

Where:

HDD = Heating Degree Days

= Dependent on location:[890]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[891] – If unknown, assume 74%[892] for unsealed ducts or 87% for sealed ducts

100,000 = Converts Btu to Therms

Other factors as defined above

For example, for a single family home in Mason City with 990 ft^2 of R-5 walls insulated to R-13, with a gas furnace with system efficiency of 87% with sealed ducts:

ΔTherms = ((1/5 - 1/13) * 990 * (1-0.25) * 6391 * 24 * 0.63) / (0.74 * 100,000)

= 101.5 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[893]

[890] 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.

[891] 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.

[892] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

[893] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, for a single family home in Mason City with 990 ft^2 of R-5 walls insulated to R-13, with a gas furnace with system efficiency of 87% and sealed ducts:

ΔPeakTherms = 101.5 * 0.016525

= 1.7 therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-SHL-WINS-V03-200101

Sunset Date: 1/1/2022

2.6.5 Insulated Doors

Description

Energy and demand saving are realized through reductions in the building cooling and heating loads.

If sealing of ducts is unknown, the sealed efficiency should be used.

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 insulation levels that exceed code requirements and should be determined by the program.

Definition of Baseline Equipment

The retrofit baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire door assembly.

Deemed Lifetime of Efficient Equipment

The measure expected useful life (EUL) is assumed to be 25 years.[894]

Deemed Measure Cost

For retrofit projects, full installation costs should be used.

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Energy Savings

Electric Energy Savings

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

$$\Delta kWh = \Delta kWhcooling + \Delta kWhheating$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta \mathrm{kWh}_{\mathrm{cooling}} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CDD * 24 * DUA}{(1{,}000 * \eta_{cooling})}$$

[894] FannieMae Estimated useful life tables for multifamily properties.

Where:

$R_{existing}$ = Existing door heat loss coefficient [(hr-^{o}F-ft^2)/Btu]. If unknown, assume 3.125[895]

R_{new} = New door heat loss coefficient [(hr-^{o}F-ft^2)/Btu]

Area = Area of the door surface in square feet.

CDD = Cooling Degree Days

= Dependent on location[896]:

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown (Des Moines)	1,068

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [897]

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate) – If unknown, assume the following:[898]

Age of Equipment	ηCool Estimate Sealed Duct Estimate	ηCool Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	10	8.5
2006 – 2014	13	11
Central AC after 1/1/2015	13	11
Heat Pump after 1/1/2015	14	12

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

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * HDD * 24}{(3{,}412 * \eta_{heating})}$$

Where:

HDD = Heating Degree Days

[895] IECC 2012 and 2015 requirements

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

[897] 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.

[898] 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.

= Dependent on location:[899]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

$\eta_{heating}$ = Efficiency of heating system

= Actual – If not available, refer to default table below:[900]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

3,142 = Conversion from Btu to kWh.

For example, for a single family home in Mason City installing a new 21 ft^2 insulated door with an R-value of 11, savings with a 10.5 SEER central AC system and a 2.26 (1.92 including distribution losses) COP Heat Pump:

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

$= (((1/3.125 – 1/11) * 21 * 616 * 24 * 0.75) / (1000 * 10.5)) + (((1/3.125 – 1/11) *21 * 6{,}391 * 24) / (3{,}412 * 1.92))$

= 5.1 kWh + 112.6 kWh

= 117.7 kWh

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta Therms * F_e * 29.3$$

Where:

$\Delta Therms$ = Gas savings calculated with equation below.

F_e = Percentage of heating energy consumed by fans, assume 3.14%[901]

29.3 = Conversion from therms to kWh

[899] 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.

[900] 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.

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

For example, for a single family home in Mason City installing a new 21 ft^2 insulated door with an R-value of 11, savings with a gas furnace with system efficiency of 74%:

ΔkWh = 10.0 * 0.0314 * 29.3

= 9.2 kWh

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[902]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home conditioning[903], 43.1%[904] for ductless HP used as supplemental or limited zone

For example, for a single family home in Mason City installing a new 21 ft^2 insulated door with an R-value of 11, savings for a 10.5 SEER central AC system:

ΔkW = 5.1 / 468 * 0.68

= 0.0074 kW

Natural Gas Savings

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * HDD * 24}{(100{,}000 * \eta_{heat})}$$

Where:

$R_{existing}$ = Existing door heat loss [(hr-°F-ft^2)/Btu]

R_{new} = New door heat loss coefficient [(hr-°F-ft^2)/Btu]

Area = Area of the door surface in square feet.

[902] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).
[903] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.
[904] Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

HDD = Heating Degree Days

= Dependent on location:[905]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[906] – If unknown, assume 74%[907] for unsealed ducts or 87% for sealed ducts

For example, for a single family home in Mason City installing a new 21 ft^2 insulated door with an R-value of 11, savings with a gas furnace with system efficiency of 74%:

ΔTherms = (((1/3.125 – 1/11) * 21 * 6,391 * 24) / (100,000 * 0.74))

= 10.0 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[908]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, for a single family home in Mason City installing a new 21 ft^2 insulated door with an R-value of 11, savings with a gas furnace with system efficiency of 74%:

ΔPeakTherms = 10.0 * 0.016525

= 0.1653 therms

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[905] 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.

[906] 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.

[907] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

[908] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-DOOR-V03-200101

SUNSET DATE: 1/1/2021

2.6.6 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 or unconditioned garage and should not be used in other situations.

Note unconditioned means a space that is not intentionally heated via furnace vents or boiler radiators. The presence of and/or leakage from a heating system in a space doesn't in itself imply the space is conditioned.

If sealing of ducts is unknown, the sealed efficiency should be used.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no insulation on any surface surrounding a crawl space or garage.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[909]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

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

Algorithm

Calculation of Savings

Electric Energy Savings

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * Area * (1 - Framing\ Factor) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Old} = R-value value of floor before insulation, assuming 3/4” plywood subfloor and carpet with pad

= Actual. If unknown assume 3.96 [910]

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

= Actual[911]

Area = Total floor area to be insulated

Framing Factor = Adjustment to account for area of framing

= 12% [912]

24 = Converts hours to days

CDD = Cooling Degree Days

Climate Zone (City based upon)	Unconditioned Space CDD 75 [913]
Zone 5 (Burlington)	411
Zone 6 (Mason City)	264
Average/ unknown (Des Moines)	474

[910] 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

[911] If open cavity, add new insulation value to the default or evaluated existing assembly R-value (R_{old}). If closed cavity, since you are displacing one or two air layers, reduce the default or evaluated existing assembly R-value by one and add to new insulation. Note, if existing insulation is added to/not removed – always re-evaluate R-value of existing insulation as it may have been degraded significantly due to compression etc.

[912] ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1

[913] The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. Five year average cooling degree days with 75F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72F.

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [914]

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:[915]

Age of Equipment	ηCool Estimate Sealed Duct Estimate	ηCool Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	10	8.5
2006 – 2014	13	11
Central AC After 1/1/2015	13	11
Heat Pump After 1/1/2015	14	12

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * Area * (1 - Framing\ Factor) * HDD * 24 * ADJ_{Floor}}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days:

Climate Zone (City based upon)	Unconditioned Space HDD 50 [916]
Zone 5 (Burlington)	2,678
Zone 6 (Mason City)	4,222
Average/ unknown (Des Moines)	3,126

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[917]

[914] Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[915] 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.

[916] The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

[917] 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) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

ADJ_{Floor} = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings.

= 88%[918]

Other factors as defined above

> **For example**, a single family home in Mason City 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 * 264*0.75)/(1000*10.5) + (((1/3.96 - 1/(30+3.96))*(20*25)*(1-0.12) * 24 * 4222)/(3412*1.92)) * 0.88)
>
> = (44.4 + 1336.0)
>
> = 1380.4 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%[919]

29.3 = kWh per therm

> **For example,** a single family home in Mason City with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 74% efficient furnace (for therm calculation see Natural Gas Savings section):
>
> ΔkWh = 118.3 * 0.0314 * 29.3
>
> = 108.8 kWh

Summer Coincident Peak Demand Savings

$$\Delta kW = \frac{\Delta kWh\_cooling}{FLH\_cooling} * CF$$

Where:

[918] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: “Home Energy Services Impact Evaluation”, August 2012. See “Insulation ADJ calculations.xls” for details or calculation. Note that basement wall is used as a proxy for crawlspace ceiling.

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

FLH_cooling = Full load hours of air conditioning

= Dependent on location[920]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home conditioning[921], 43.1%[922] for ductless HP used as supplemental or limited zone

For example, a single family home in Mason City 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 = 44.4 / 468 * 0.68

= 0.0645 kW

Natural Gas Savings

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * Area * (1 - Framing\ Factor) * HDD * 24 * ADJ_{Floor}}{(\eta Heat * 100{,}000)}$$

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[923] – If unknown, assume 74%[924] for unsealed ducts or 87% for sealed ducts

100,000 = Converts Btu to Therms

Other factors as defined above

[920] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

[921] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[922] Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

[923] 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.

[924] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

For example, a single family home in Mason City with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 74% efficient furnace:

ΔTherms = (((1/3.96-1/(30+3.96))*(20*25)*(1-0.12)*24*4222)/(100000*0.74))*0.88

= 118.3 therms

Peak Gas Savings

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[925]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, a single family home in Mason City with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 74% efficient furnace:

ΔPeakTherms = 118.3 therms * 0.016525

= 1.95 therms

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

Measure Code: RS-SHL-FINS-V04-200101

Sunset Date: 1/1/2021

[925] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.6.7 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.

Note unconditioned means a space that is not intentionally heated via furnace vents or boiler radiators. The presence of and/or leakage from a heating system in a space doesn't in itself imply the space is conditioned.

If sealing of ducts is unknown, the sealed efficiency should be used.

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

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

Definition of Efficient Equipment

The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no basement wall or ceiling insulation.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 25 years.[926]

Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

Deemed O&M Cost Adjustments

N/A

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Savings

Electric Energy Savings

Where available savings from shell insulation measures should be determined through a custom analysis. When that

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

is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

= Actual[927]

R_{OldAG} = R-value value of foundation wall above grade.

= Actual, if unknown assume 1.0[928]

L_{BWT} = Length (Basement Wall Total) of basement wall around the entire insulated perimeter (ft)

H_{BWAG} = Height (Basement Wall Above Grade) of insulated basement wall above grade (ft)

FF = Framing Factor, an adjustment to account for area of framing when cavity insulation is used

= 0% if Spray Foam or External Rigid Foam

= 25% if studs and cavity insulation[929]

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:

Climate Zone (City based upon)	Conditioned Space CDD 65 [930]	Unconditioned Space CDD 75 [931]
Zone 5 (Burlington)	1,209	411
Zone 6 (Mason City)	616	264
Average/ unknown (Des Moines)	1,068	474

[927] If open cavity, add new insulation value to the default or evaluated existing assembly R-value (R_{old}). If closed cavity, since you are displacing one or two air layers, reduce the default or evaluated existing assembly R-value by one and add to new insulation. Note, if existing insulation is added to/not removed – always re-evaluate R-value of existing insulation as it may have been degraded significantly due to compression etc.

[928] ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991. See reference file "ORNL Builders Foundation Handbook." f

[929] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

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

[931] The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. Five year average cooling degree days with 75F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72F.

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 Sealed Duct Estimate	ηCool Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	10	8.5
2006 – 2014	13	11
Central AC After 1/1/2015	13	11
Heat Pump After 1/1/2015	14	12

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\begin{array}{c}\left(\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF)\right) + \\ \left(\left(\frac{1}{R_{OldBG}} - \frac{1}{(R_{Added} + R_{OldBG})}\right) * L_{BWT} * (H_{BWT} - H_{BWAG}) * (1 - FF)\right)\end{array}\right) * HDD * 24 * DUA * ADJ_{Basement}}{(3412 * \eta Heat)}$$

Where

R_{OldBG} = R-value value of foundation wall below grade (including thermal resistance of the earth) [934]

= dependent on depth of foundation (H_basement_wall_total – H_basement_wall_AG):

= Actual R-value of wall plus average earth R-value by depth in table below

For example, for an area that extends 5 feet below grade, an R-value of 7.46 would be selected and added to the existing insulation R-value.

Below Grade R-value									
Depth below grade (ft)	0	1	2	3	4	5	6	7	8
Earth R-value (°F-ft^2-h/Btu)	2.44	4.50	6.30	8.40	10.44	12.66	14.49	17.00	20.00
Average Earth R-value (°F-ft2-h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69
Total BG R-value (earth + R-1.0 foundation) default	3.44	4.47	5.41	6.41	7.42	8.46	9.46	10.53	11.69

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 Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

H_{BWT} = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space
	HDD 60 [935]	HDD 50 [936]
Zone 5 (Burlington)	4,496	2,678
Zone 6 (Mason City)	6,391	4,222
Average/ unknown (Des Moines)	5,052	3,126

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[937]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

$ADJ_{Basement}$= Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings.

= 88%[938]

[935] 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.

[936] The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

[937] 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.

[938] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation", August 2012. See "Insulation ADJ calculations.xls" for details or calculation.

For example, a single family home in Mason City with a 20 by 25 by 7 foot R-2.25 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:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= [(((1/2.25 - 1/(13 + 2.25))*(20+25+20+25) * 3 * (1 - 0)) * 24 * 264 * 0.75)/(1000 * 10.5)] + [(((((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 * 4222) / (3412 * 1.92)) * 0.88]

= (46.3 + 1731.4.0)

= 1777.7 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%[939]

29.3 = kWh per therm

For example, a single family home in Mason City 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 74% efficient furnace (for therm calculation see Natural Gas Savings section :

= 153.3 * 0.0314 * 29.3

= 141 kWh

Summer Coincident Peak Demand

$$\Delta kW = \frac{\Delta kWh\_cooling}{FLH\_cooling} * CF$$

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[940]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home

[939] 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.

[940] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

conditioning[941], 43.1%[942] for ductless HP used as supplemental or limited zone\

> **For example**, a single family home in Mason City 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 = 46.3 / 468 * 0.68
>
> = 0.0673 kW

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms =

$$= \frac{\left(\begin{array}{c}\left(\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF)\right) + \\ \left(\left(\frac{1}{R_{OldBG}} - \frac{1}{(R_{Added} + R_{OldBG})}\right) * L_{BWT} * (H_{BWT} - H_{BWAG}) * (1 - FF)\right)\end{array}\right) * HDD * 24 * ADJ_{Basement}}{(100{,}000 * \eta Heat)}$$

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[943] – If unknown, assume 74%[944] for unsealed ducts or 87% for sealed ducts

100,000 = Converts Btu to Therms

Other factors as defined above

> **For example**, a single family home in Mason City 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 74% 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 * 4222) / (0.74 * 100,000) * 0.88
>
> = 153.3 therms

[941] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[942] Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

[943] 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.

[944] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[945]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, a single family home in Mason City 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 74% efficient furnace:

ΔPeakTherms = 153.3 therms * 0.016525

= 2.53 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-BINS-V04-200101

SUNSET DATE: 1/1/2021

[945] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.6.8 Efficient Windows

Description

This measure describes savings realized by the purchase and installation of new windows that have better thermal insulating properties compared to code requirements. Code does not specify solar heat gain coefficient requirements for residential windows and therefore no impacts are quantified or claimed. For a comprehensive estimate of impacts, computer modeling is recommended.

If sealing of ducts is unknown, the sealed efficiency should be used.

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

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

Definition of Efficient Equipment

The efficient solution is a window assembly with a U-factor that is better than code.

Definition of Baseline Equipment

The baseline condition is a window assembly with a U-factor equal to code requirements.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[946]

Deemed Measure Cost

The incremental cost for this measure is assumed to be $1.50 per square foot of window area.[947]

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Savings

The following calculations apply to a single window assembly.

Electric Energy Savings

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

Where:

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to insulation

[946] Consistent with window measure lives specified in the MidAmerican Energy Company Joint Assessment, February 2013.
[947] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007.

$$= \frac{(U_{code} - U_{eff}) * A_{window} * CDD * 24 * DUA}{(1000 * \eta_{cool})}$$

U_{code} = U-factor value of code baseline (IECC2012) window assembly (Btu/ft^2.°F.h)

= 0.32 (Btu/ft^2.°F.h) or 0.55 (Btu/ft^2.°F.h) for skylights.

U_{eff} = U-factor value of the efficient window assembly (Btu/ft^2.°F.h)

= Actual.

A_{window} = Area of insulated window (including visible framing and glass) (ft^2)

CDD = Cooling Degree Days

= Dependent on location[948]:

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown (Des Moines)	1,068

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [949]

1000 = Converts Btu to kBtu

η_{cool} = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate) – If unknown, assume the following:[950]

Age of Equipment	ηCool Sealed Duct Estimate	ηCool Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	10	8.5
2006 – 2014	13	11
Central AC after 1/1/2015	13	11
Heat Pump after 1/1/2015	14	12

$kWh_{heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

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

949 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.

950 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.

$$= \frac{(U_{code} - U_{eff}) * A_{window} * HDD * 24 * ADJ_{window}}{(\eta_{heat} * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:[951]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

η_{heat} = Efficiency of heating system

= Actual – If not available, refer to default table below:[952]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

3412 = Converts Btu to kWh

ADJ_{window} = Adjustment for account for prescriptive engineering algorithms consistently overclaiming savings

= 63%[953]

Other factors as defined above.

[951] 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.

[952] 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.

[953] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: “Home Energy Services Impact Evaluation”, August 2012. See “Insulation ADJ calculations.xls” for details or calculation. The adjustment for walls was assumed to be an appropriate adjustment for windows.

For example, for a single family home in Mason City installs 15 new identically sized 2' x 4' windows with a 0.25 U-Factor. Savings for a 10.5 SEER Central AC system and a 2.26 (1.92 including distribution losses) COP Heat Pump:

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

$= ((((0.32 – 0.25) * 8 * 616 * 24 * 0.75) / (1000 * 10.5)) + (((0.32 – 0.25) * 8 * 6391 * 24 * 0.63) / (1.92 * 3412))) * 15$

= 9 kWh + 124 kWh

= 133 kWh

$\Delta kWh_{heating}$ = If gas *furnace* heat, kWh savings for reduction in fan run time

$= \Delta Therms * F_e * 29.3$

Where:

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

= 3.14%[954]

29.3 = kWh per therm

For example, for a single family home in Mason City installs 15 new identically sized 2' x 4' windows with a 0.25 U-Factor. Savings with a gas furnace with system efficiency of 74%:

$\Delta kWh = 11 * 0.0314 * 29.3$

= 10 kWh

Summer Coincident Peak Demand Savings

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

Where:

$FLH_{cooling}$ = Full load hours of air conditioning

= Dependent on location[955]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home

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

[955] Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

conditioning[956], 43.1%[957] for ductless HP used as supplemental or limited zone

For example, for a single family home in Mason City installs 15 new identically sized 2' x 4' windows with a 0.25 U-Factor. Savings for a 10.5 SEER Central AC system and a 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkW = 9 / 468 * 0.68

= 0.0131 kW

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{(U_{code} - U_{eff}) * A_{window} * HDD * 24 * ADJ_{window}}{(\eta_{heat} * 100{,}000)}$$

Where:

η_{heat} = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[958] – If unknown, assume 74%[959] for unsealed ducts or 87% for sealed ducts

100,000 = Converts Btu to Therms

Other factors as defined above.

For example, for a single family home in Mason City installs 15 new identically sized 2' x 4' windows with a 0.25 U-Factor. Savings with a gas furnace with system efficiency of 74%:

ΔTherms = [(0.32 – 0.25) * 8 * 6391 * 24 * 0.63) / (0.74 * 100,000))] * 15

= 11 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[960]

[956] Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[957] Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

[958] 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.

[959] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

[960] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, for a single family home in Mason City installs 15 new identically sized 2' x 4' windows with a 0.25 U-Factor. Savings with a gas furnace with system efficiency of 74%:

ΔPeakTherms = 11 * 0.016525

= 0.18 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-WINS-V03-200101

SUNSET DATE: 1/1/2021

2.6.9 Window Insulation Kits

Description

This measure describes savings from installing seasonal window insulation kits during the heating season. Kits generally include tape and shrink film that is applied to window moldings to create a static air layer between the interior of the home and the window surface. There are three principal mechanisms that constitute heat transfer through windows: Air leakage/infiltration, temperature driven heat transfer, and solar gains. Due to the complexities and uncertainties related to estimating how air leakage/infiltration rates may be affected by retrofit activities, and the potential for double-counting savings claimed through separate air sealing measures, only temperature driven heat transfer is considered. Window insulation kits are considered a seasonal measure during the heating season and thus savings are only heating energy savings are claimed.

It is recommended that a member of the implementation staff evaluate the pre- and post-project R-values, measure surface areas, and evaluate the efficiency of the heating equipment in the home. Additionally, installation quality should be verified, as this measure relies on the creation of a static air layer to be effective.

If sealing of ducts is unknown, the sealed efficiency should be used.

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 solution is one that effectively creates a static air layer in series with the existing window (can be on either side of the window) and the outdoor environment. The requirements for participation in the program will be defined by the utilities.

Definition of Baseline Equipment

The existing condition is the pre-retrofit window assembly.

Deemed Lifetime of Efficient Equipment

The expected measure life is one year.

Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

Loadshape

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Savings

The following calculations apply to a single window assembly.

Electric Energy Savings

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

$kWh_{heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Old} + R_{New}}\right) * A_{window} * HDD * 24 * ADJ_{window}}{(\eta_{heat} * 3412)}$$

R_{Old} = R-value value of existing window assembly (ft^2.°F.h/Btu)

= Actual. If unknown, assume R-2[961]

R_{New} = R-value of added air layer (ft^2.°F.h/Btu)

= R-2.85[962].

A_{window} = Net area of insulated window (ft^2)

= Actual. If unknown, assume 8 ft^2 (24 inch x 48 inch)

HDD = Heating Degree Days

= Dependent on location:[963]

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown (Des Moines)	5,052

η_{heat} = Efficiency of heating system

= Actual – If not available, refer to default table below:[964]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

3412 = Converts Btu to kWh

ADJ_{window} = Adjustment for wall insulation to account for prescriptive engineering algorithms

[961] A typical R-value for a double-pane window and consistent with the assumptions outlined in the MidAmerican Energy Company Joint Assessment (February 2013) for existing windows.

[962] Based on PNNL report 2444-2. Experimental data showed that an air gap greater than 0.5 inches had virtually no impact on insulation properties, and that and R-value of 2.85 is expected for any air gap greater than 0.5 inches.

[963] 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.

[964] 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.

consistently overclaiming savings

= 63%[965]

For example, for a single family home in Mason City with 15 identically sized 2' x 4' windows installs window insulation film with a 4-inch air layer. Heating savings with a 2.26 (1.92 including distribution losses) COP Heat Pump:

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

$= [(1/2 - 1/(2+4)) * 8 * 6391 * 24 * 0.63) / (1.92 * 3412))] * 15$

= 590 kWh

$\Delta kWh_{heating}$ = If gas *furnace* heat, kWh savings for reduction in fan run time

$= \Delta Therms * F_e * 29.3$

Where:

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

= 3.14%[966]

29.3 = kWh per therm

For example, for a single family home in Mason City with 15 identically sized 2' x 4' windows installs window insulation film with a 4-inch air layer. Savings with a gas furnace with system efficiency of 74%:

$\Delta kWh = 52 * 0.0314 * 29.3$

= 48 kWh

Summer Coincident Peak Demand Savings

N/A

Natural Gas Savings

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Old} + R_{New}}\right) * A_{window} * HDD * 24 * ADJ_{window}}{(\eta_{heat} * 100{,}000)}$$

Where:

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

965 Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation", August 2012. See "Insulation ADJ calculations.xls" for details or calculation. The adjustment for walls was assumed to be an appropriate adjustment for windows.

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

= Actual[967] – If unknown, assume 74%[968] for unsealed ducts or 87% for sealed ducts

100,000 = Converts Btu to Therms

Other factors as defined above

> **For example**, for a single family home in Mason City with 15 identically sized 2' x 4' windows installs window insulation film with a 4-inch air layer. Savings with a gas furnace with system efficiency of 74%:
>
> ΔTherms = [(1/2 - 1/(2+4)) * 8 * 6391 * 24 * 0.63) / (0.74 * 100,000))] * 15
>
> = 52 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[969]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

> **For example**, for a single family home in Mason City with 15 identically sized 2' x 4' windows installs window insulation film with a 4-inch air layer. Savings with a gas furnace with system efficiency of 74%:
>
> ΔPeakTherms = 52 * 0.016525
>
> = 0.86 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-WINK-V02-200101

SUNSET DATE: 1/1/2023

[967] 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.

[968] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

[969] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.6.10 Storm Windows

Description

Storm windows installed on either the interior or exterior of existing window assemblies can reduce both heating and cooling loads by reducing infiltration and solar heat gain, and improving insulation properties. Glass options for storm windows can include traditional clear glazing as well as low-emissivity (Low-E) glazing. Low-E glass is formed by adding an ultra-thin layer of metal to clear glass. The metallic-oxide (pyrolytic) coating is applied when the glass is in its molten state, and the coating becomes a permanent and extremely durable part of the glass. This coating is also known as "hard-coat" Low-E. Low-E glass is designed to redirect heat back towards the source, effectively providing higher insulating properties and lower solar heat gain as compared to traditional clear glass. This characterization captures the savings associated with installing storm windows to an existing window assembly (retrofit).

If sealing of ducts is unknown, the sealed efficiency should be used.

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

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

Definition of Efficient Equipment

An interior or exterior storm window installed according to manufacturer specifications.

Definition of Baseline Equipment

The existing window assembly.

Deemed Lifetime of Efficient Equipment

20 years[970]

Deemed Measure Cost

The actual capital cost for this measure should be used when available and include both material and labor costs. If unavailable, the cost for a low-e storm window can be assumed as $7.85/ft^2$ of window area (material cost) plus $30 per window for installation expenses[971]. For clear glazing, cost can be assumed as $6.72/ft^2$ of window area (material cost) plus $30 per window for installation expenses[972]

Loadshape

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

[970] Task ET-WIN-PNNL-FY13-01_5.3: Database of Low-e Storm Window Energy Performance across U.S. Climate Zones. KA Cort and TD Culp, September 2013. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory. PNNL-22864.
[971] Task ET-WIN-PNNL-FY13-01_5.3: Database of Low-e Storm Window Energy Performance across U.S. Climate Zones. KA Cort and TD Culp, September 2013. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory. PNNL-22864.
[972] A comparison of low-e to clear glazed storm windows available at large national retail outlets showed the average incremental cost for low-e glazing to be $1.13/ft^2$. Installation costs are identical.

Loadshape RG04 – Residential Other Heating

Algorithm

Calculation of Savings

The following reference tables show savings factors (kBtu/ft^2) for both heating and cooling loads for each of the weather zones defined by the TRM[973]. They are used with savings equations listed in the electric energy and gas savings sections to produce savings estimates. If storm windows are left installed year-round, both heating and cooling savings may be claimed. If they are installed seasonally, only heating savings should be claimed. Savings are dependent on location, storm window location (interior or exterior), glazing type (clear or Low-E) and existing window assembly type.

Zone 5 (Burlington)

Heating:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	58.4	17.3	59.2	15.9
	CLEAR INTERIOR	60.9	22.5	60.1	18.0
	LOW-E EXTERIOR	64.2	18.4	66.1	23.7
	LOW-E INTERIOR	71.0	25.9	69.1	22.6

Cooling:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	22.9	10.4	22.4	9.5
	CLEAR INTERIOR	23.8	10.7	24.3	9.7
	LOW-E EXTERIOR	29.3	15.3	29.1	9.1
	LOW-E INTERIOR	28.5	14.0	28.8	13.3

Zone 6 (Mason City)

Heating:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	91.3	28.6	92.1	26.3
	CLEAR INTERIOR	95.3	35.8	94.5	29.6
	LOW-E EXTERIOR	102.0	32.4	104.3	36.4
	LOW-E INTERIOR	110.7	41.9	108.4	37.3

Cooling:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm	CLEAR EXTERIOR	14.9	7.6	14.4	6.9

[973] Savings factors are based on simulation results, documented in “Storm Windows Savings.xlsx”

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Window Type	CLEAR INTERIOR	15.5	7.4	16.0	6.9
	LOW-E EXTERIOR	20.1	11.8	19.7	6.0
	LOW-E INTERIOR	18.8	10.0	19.2	9.7

Average/Unknown (Des Moines)

Heating:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	70.3	21.4	71.1	19.7
	CLEAR INTERIOR	73.3	27.3	72.5	22.2
	LOW-E EXTERIOR	77.9	23.5	80.0	28.4
	LOW-E INTERIOR	85.4	31.8	83.3	28.0

Cooling:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	20.0	9.4	19.5	8.5
	CLEAR INTERIOR	20.8	9.4	21.3	8.7
	LOW-E EXTERIOR	25.9	13.9	25.5	7.9
	LOW-E INTERIOR	24.9	12.4	25.2	11.9

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$$

Where:

ΔkWh_cooling = If storm windows are left installed during the cooling season and the home has central cooling, the reduction in annual cooling requirement

$$= \frac{\varphi_{cool} * A}{\eta Cool}$$

φ_{cool} = Savings factor for cooling, as tabulated above.

A = Area (square footage) of storm windows installed.

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

= Actual (where it is possible to measure or reasonably estimate) – If unknown, assume the following[974]:

Age of Equipment	SEER Sealed Estimate	SEER Unsealed Estimate
Before 2006	10	8.5
2006 – 2014	13	11
Central AC After 1/1/2015	13	11
Heat Pump After 1/1/2015	14	12

[974] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating

$$= \frac{\varphi_{heat} * A}{\eta Heat * 3.412}$$

φ_{heat} = Savings factor for heating, as tabulated above.

ηHeat = Efficiency of heating system

= Actual – If not available refer to default table below[975]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF/3.412)
Heat Pump	Before 2006	6.8	1.69	1.99
	2006 – 2014	7.7	1.92	2.26
	2015 and after	8.2	2.04	2.40
Resistance	N/A	N/A	1.00	1.00

3.412 = Converts kBtu to kWh

For example, for a single family home in Mason City installing 15 new identically sized 2' x 4' exterior low-e storm windows over existing double pane, double hung windows, savings for a 10.5 SEER Central AC system and a 2.26 (1.92 including distribution losses) COP Heat Pump:

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

= (((11.8 * 8) / 10.5) + ((32.4 * 8) / (1.92 * 3.412))) * 15

= 135 kWh + 593 kWh

= 728 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

Where:

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

= 3.14%[976]

29.3 = kWh per therm

[975] 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.

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

For example, for a single family home in Mason City installing 15 new identically sized 2' x 4' exterior low-e storm windows over existing double pane, double hung windows, savings with a gas furnace with system efficiency of 74%:

ΔkWh = 52 * 0.0314 * 29.3

= 48 kWh

Summer Coincident Peak Demand Savings

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

Where:

$FLH_{cooling}$ = Full load hours of air conditioning

= Dependent on location[977]:

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	918	736	865
Zone 6 (Mason City)	468	375	441
Average/ unknown (Des Moines)	811	650	764

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC, 72% if ducted ASHP or ductless HP used for whole home conditioning[978], 43.1%[979] for ductless HP used as supplemental or limited zone

For example, for a single family home in Mason City installing 15 new identically sized 2' x 4' exterior low-e storm windows over existing double pane, double hung windows, savings for a 10.5 SEER Central AC system and a 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkW = 135 / 468 * 0.68

= 0.1962 kW

Natural Gas Savings

If Natural Gas heating:

$$\Delta Therms = \frac{\varphi_{heat} * A}{\eta Heat * 100}$$

Where:

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

977 Full load hours for Des Moines are provided based on Cadmus modeling for the 2011 Joint Assessment. The other locations were calculated based on relative Cooling Degree Day ratios (from NCDC).

978 Based on analysis of metering results from homes in Ameren Illinois service territory in PY5; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

979 Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

= Actual[980] – If not available, use 74%[981] for unsealed ducts or 87% for sealed ducts

100 = Converts kBtu to Therms

Other factors as defined above

For example, for a single family home in Mason City installing 15 new identically sized 2' x 4' exterior low-e storm windows over existing double pane, double hung windows, savings with a gas furnace with system efficiency of 74%:

ΔTherms = ((32.4 * 8) / (0.74 * 100)) * 15

= 52.5 therms

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating[982]

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, for a single family home in Mason City installing 15 new identically sized 2' x 4' exterior low-e storm windows over existing double pane, double hung windows, savings with a gas furnace with system efficiency of 74%:

ΔPeakTherms = 52.5 * 0.016525

= 0.8676 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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SUNSET DATE: 1/1/2023

[980] 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.

[981] This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74.

[982] Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.7 Miscellaneous

2.7.1 Residential 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%[983]. This measure applies to the purchase and installation 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. ENERGY STAR Pool Pump Specification Version 2.0 became effective on January 2, 2019. This characterization assumes incentivized products meet Version 2.0 requirements. Programs wishing to incentivize pumps meeting original ENERGY STAR qualification criteria should reference previous TRM versions.

Definition of Baseline Equipment

The baseline equipment is a single speed residential pool pump. Note: Federal Standards applying to pool pumps are scheduled to become effective July 19, 2021 and will trigger a baseline shift. Also scheduled to coincide are ENERGY STAR Version 3.0 specifications for pool pumps.

Deemed Lifetime of Efficient Equipment

The estimated useful life for a two speed or variable speed pool pump is 10 years[984].

Deemed Measure Cost

The incremental cost is estimated as $235 for a two speed motor and $549 for a variable speed motor[985]. In retrofit instances, full replacement costs shall be used.

Loadshape

Loadshape RE17 – Residential Pool Pumps

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

[984] 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, the expected lifetime is higher, so 10 years is selected as an assumption. This is consistent with DEER 2014 and the ENERGY STAR Pool Pump Calculator assumptions.

[985] Incremental costs are from ENERGY STAR Pool Pump Calculator.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS[986]

$$\Delta kWh_{two\ speed} = (((Hrs/Day_{Base} * GPM_{Base} * 60)/EF_{Base}) - (((Hrs/Day_{2spH} * GPM_{2spH} * 60) + (Hrs/Day_{2spL} * GPM_{2spL} * 60))/WEF_{2sp}))/1{,}000 * Days$$

$$\Delta kWh_{variable\ speed} = (((Hrs/Day_{Base} * GPM_{Base} * 60)/EF_{Base}) - (((Hrs/Day_{vsH} * GPM_{vsH} * 60) + (Hrs/Day_{vsL} * GPM_{vsL} * 60))/WEF_{vs}))/1{,}000 * Days$$

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 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

WEF_{2sp} = Weighted Energy Factor of two speed pump (gal/Wh)

= 5.6[987]

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

1,000 = Conversion factor from Wh to kWh

Days = Pool operating days per year

= 125[988]

[986] Except where noted, savings methodology and assumptions are 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.

[987] Based on the average WEF of Energy Certified pumps as of 5/6/2019. See Referenced Document "certified-pool-pumps-2019-05-06.xlsx." Note: Energy Star uses units of kgal/kWh in specification of weighted energy factors, however this is identical to gal/Wh.

[988] Assumes 50% of pools operate 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.

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

WEF_{vs} = Weighted Energy Factor of variable speed (gal/Wh)

= 8.1[989]

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

Based on defaults provided above:

$\Delta kWh_{two\ speed}$ = (((11.4 * 64.4 * 60)/2.1) - (((2* 56 * 60) + (15.7 * 31 * 60))/5.6))/1000 * 125

= 1,820.2 kWh

$\Delta kWh_{variable\ speed}$ = (((11.4 * 64.4 * 60)/2.1) - (((2* 50 * 60) + (16 * 30.6 * 60))/8.1))/1000 * 125

= 2,076.1 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW_{two\ speed} = ((kWh/Day_{Base})/(Hrs/Day_{Base}) - (kWh/Day_{sp})/(Hrs/Day_{sp})) * CF$$

$$\Delta kW_{variable\ speed} = ((kWh/Day_{Base})/(Hrs/Day_{Base}) - (kWh/Day_{var})/(Hrs/Day_{var})) * CF$$

Where:

kWh/Day_{Base} = Daily energy consumption of single speed pool pump

= 20.98

Hrs/Day_{base} = Daily run hours of single speed pump

= 11.4

kWh/Day_{2sp} = Daily energy consumption of two speed pump

= 6.41

Hr/Day_{2sp} = Daily run hours of two speed pump

= 17.7

kWh/Day_{vs} = Daily energy consumption of variable speed pump

= 4.37

Hr/Day_{vs} = Daily run hours of variable speed pump

[989] Based on the average WEF of Energy Certified pumps as of 5/6/2019 See Referenced Document "certified-pool-pumps-2019-05-06.xlsx." Note: Energy Star uses units of kgal/kWh in specification of weighted energy factors, however this is identical to gal/Wh.

= 18

CF = Summer peak coincidence Factor for measure

= 0.831[990]

$\Delta kW_{two\ speed}$ = ((20.98 / 11.4) – (6.41 / 17.7)) * 0.831

= 1.228 kW

$\Delta kW_{variable\ speed}$ = ((20.98 / 11.4) – (4.37 / 18)) * 0.831

= 1.328 kW

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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[990] Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Iowa.