

Iowa Energy Efficiency Statewide Technical Reference Manual Version 11.0

Volume 2: Residential Measures

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Volume 3: Nonresidential Measures

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 STAR¹ 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 NREL ResStockdata (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 2018.²

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."*³

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years.⁴

¹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

² See Code of Federal Regulations Title 10 Chapter II Subchapter D Part 430 Subpart A 430.2.

³ Definitions provided in ENERGY STAR v8.1 specification on the ENERGY STAR website.

⁴ Based on DOE Chapter 8 Life-Cycle Cost and Payback Period Analysis, pg 8-7.

DEEMED MEASURE COST

The incremental cost assumptions are provided below:⁵

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

$$\Delta kWh = \left[\left(Capacity * \frac{1}{IMEF_{base}} * Ncycles \right) * (\%CW_{base} + (\%DHW_{base} * \%Electric_{DHW}) + (\%Dryer_{base} * \%Electric_{Dryer})) \right] - \left[\left(Capacity * \frac{1}{IMEF_{eff}} * Ncycles \right) * (\%CW_{eff} + (\%DHW_{eff} * \%Electric_{DHW}) + (\%Dryer_{eff} * \%Electric_{Dryer})) \right]$$

Where:

- Capacity = Clothes Washer capacity (cubic feet)
 = Actual; if capacity is unknown, assume 4.14 cubic feet⁶
- 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 ⁷
Federal Standard	1.57	1.84	1.61

- IMEFeff = Integrated Modified Energy Factor of efficient unit
 = Actual; if unknown, assume average values provided below

⁵ Based on cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool. See analysis for details.

⁶ Based on the average clothes washer volume of all units that either pass the new Federal Standard, ENERGY STAR Specifications or CEE Tier 2, as found in the US DOE EERE Compliance Certification Database, accessed April 2023. 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.

⁷ 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 US DOE EERE Compliance Certification Database, accessed April 2023. Please see the analysis file for further details.

Efficiency Level	IMEFeff		
	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft	Weighted Average ⁸
ENERGY STAR	2.06	2.76	2.30
CEE Tier 2	2.92		2.92

Ncycles = Number of Cycles per year

= 250⁹

%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)¹⁰

Top-Loading			Front-Loading		
Machine	Water	Drying	Machine	Water	Drying
4%	37%	59%	10%	21%	69%
4%	29%	67%	14%	10%	77%
4%	29%	67%	14%	10%	77%

All ¹¹		
Machine	Water	Drying
5%	34%	61%
8%	22%	70%
14%	10%	77%

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

DHW Fuel	%Electric _{DHW}
Electric	100%
Natural Gas	0%
Unknown	38.4% ¹²

⁸ Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and CEE Tier 2 certified products in the US DOE EERE Compliance Certification Database, accessed April 2023.

⁹ 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. See '2025 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.

¹⁰ 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 Analysis for details.

¹¹ Weighted average of front-loading and top-loading %Dryer values, please see analysis file for weighting

¹² Default assumption for unknown fuel is based on NREL ResStock building characteristic data released in 2022. If utilities have

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

Dryer Fuel	%Electric _{Dryer}
Electric	100%
Natural Gas	0%
Unknown	87.8% ¹³

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

Front Loaders:

Efficiency Level	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	187.4	103.2	87.9	3.7
CEE Tier 2	208.0	121.8	92.8	6.6

Top Loaders:

Efficiency Level	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	156.8	60.0	102.4	5.7
CEE Tier 2	304.7	165.0	151.7	12.0

Weighted Average:

Efficiency Level	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	192.2	71.8	118.5	-1.9
CEE Tier 2	287.6	100.7	169.9	-17.0

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

Efficiency Level	ΔkWH		
	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR	123.4	90.6	109.1
CEE Tier 2	140.8	200.0	158.1

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

¹³ Default assumption for unknown is based on percentage of homes with clothes washers that use an electric dryer from NREL ResStock building characteristic data released in 2022. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

ΔkWh	= Energy Savings as calculated above
Hours	= Assumed Run hours of Clothes Washer = 250 hours ¹⁴
CF	= Summer Peak Coincidence Factor for measure = 3.6% ¹⁵

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

Front Loaders:

Efficiency Level	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0270	0.0149	0.0127	0.0005
CEE Tier 2	0.0300	0.0175	0.0134	-0.0009

Top Loaders:

Efficiency Level	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0226	0.0086	0.0147	0.0008
CEE Tier 2	0.0439	0.0238	0.0218	0.0017

Weighted Average:

Efficiency Level	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0277	0.0103	0.0171	-0.0003
CEE Tier 2	0.0414	0.0145	0.0245	-0.0025

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

Efficiency Level	ΔkW		
	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR	0.0178	0.0130	0.0157
CEE Tier 2	0.0203	0.0288	0.0228

¹⁴ Based on a weighted average of 250 clothes washer cycles per year assuming an average load runs for one hour.

¹⁵ Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, using IA definition of summer peak period.

NATURAL GAS SAVINGS

$$\Delta Therms = \left[\left[\left(Capacity * \frac{1}{IMEF_{base}} * Ncycles \right) * \left((\%DHW_{base} * \%Natural\ Gas_{DHW} * R_{eff}) + (\%Dryer_{base} * \%Gas_{Dryer}) \right) \right] - \left[\left(Capacity * \frac{1}{IMEF_{eff}} * Ncycles \right) * \left((\%DHW_{eff} * \%Gas_{DHW} * R_{eff}) + (\%Dryer_{eff} * \%Gas_{Dryer}) \right) \right] \right] * Therm_{convert}$$

Where:

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

DHW Fuel	$\%Gas_{DHW}$
Electric	0%
Natural Gas	100%
Unknown	61.6% ¹⁶

R_{eff} = Recovery efficiency factor

= 1.26¹⁷

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

Dryer Fuel	$\%Gas_{Dryer}$
Electric	0%
Natural Gas	100%
Unknown	12.2% ¹⁸

$Therm_{convert}$ = 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:

Efficiency Level	$\Delta Therms$			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0	3.6	3.4	7.0
CEE Tier 2	0.0	3.7	3.9	7.6

Top Loaders:

Efficiency Level	$\Delta Therms$			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0	4.2	1.9	6.0

¹⁶ Default assumption for unknown fuel is based on ResStock data for the state of Iowa.

¹⁷ To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency. Therefore a factor of 0.98/0.78 (1.26) is applied.

¹⁸ Default assumption for unknown fuel is based on ResStock data for the state of Iowa.

Efficiency Level	Δ Therms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
CEE Tier 2	0.0	6.0	5.2	11.2

Weighted Average:

Efficiency Level	Δ Therms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0	5.2	2.5	7.7
CEE Tier 2	0.0	8.0	4.0	12.1

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

Efficiency Level	Δ Therms		
	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR	2.6	2.8	3.5
CEE Tier 2	2.8	4.3	5.4

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:

$$\Delta PeakTherms = \frac{\Delta Therms}{365}$$

Where:

Δ Therms = Therm impact calculated above

365 = Days per year

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

Front Loaders:

Efficiency Level	Δ PeakTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0000	0.0099	0.0093	0.0192
CEE Tier 2	0.0000	0.0101	0.0108	0.0209

Top Loaders:

Efficiency Level	Δ PeakTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0000	0.0114	0.0051	0.0165
CEE Tier 2	0.0000	0.0164	0.0143	0.0307

Weighted Average:

Efficiency Level	Δ PeakTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0000	0.0142	0.0069	0.0211
CEE Tier 2	0.0000	0.0220	0.0110	0.0330

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

Efficiency Level	Δ PeakTherms		
	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR	0.0072	0.0076	0.0096
CEE Tier 2	0.0076	0.0119	0.0149

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta \text{Water (gallons)} = \text{Capacity} * (\text{IWF}_{\text{base}} - \text{IWF}_{\text{eff}}) * \text{Ncycles}$$

Where:

IWF_{base} = Integrated Water Factor of baseline clothes washer

= 6.22¹⁹

IWF_{eff} = Water Factor of efficient clothes washer

= Actual – If unknown assume average values provided below

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

Efficiency Level	IWF ²⁰			Δ Water (gallons per year)		
	Front Loaders	Top Loaders	Weighted Average	Front Loaders	Top Loaders	Weighted Average
Federal Standard	4.7	6.5	6.22	N/A		
ENERGY STAR	3.2	4.3	3.92	1,552.1	2,276.4	2,379
CEE Tier 2	3.2		3.20	1,552.1	3,414.5	3,414.5

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-CLWA-V06-260101

SUNSET DATE: 1/1/2028

¹⁹ 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 CCMS database.

²⁰ 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 CEE Tier 2 qualified products, based on the CCMS database.

2.1.2 Clothes Dryer

DESCRIPTION

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR²¹, 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.²² 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. As of 2023 the ENERGY STAR Most Efficient criteria now excludes Gas Dryers.

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 years²³

DEEMED MEASURE COST

The incremental cost for an ENERGY STAR clothes dryer is assumed to be as follows:²⁴

Product Class	Incremental Cost	
	Non-IQ	IQ
Vented Electric, Standard (≥ 4.4 ft ³)	\$61	\$138
Ventless Electric, Standard (≥ 4.4 ft ³)	\$61	\$138
Most Efficient Vented Hybrid, Standard	\$127	\$193
Most Efficient Ventless Hybrid, Standard	\$127	\$193
Full Heat Pump, Standard	\$412	\$489
Vented Electric, Compact (120V) (< 4.4 ft ³)	\$31	\$109
Ventless Electric, Compact (120V) (< 4.4 ft ³)	\$31	\$109
Vented Electric, Compact (240V) (< 4.4 ft ³)	\$90	\$168
Ventless Electric, Compact (240V) (< 4.4 ft ³)	\$90	\$168
Vented Gas	\$104	\$195

²¹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

²² ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011.

²³ Based on DOE Rulemaking Technical Support Document, LCC Chapter, 2011, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

²⁴ Based upon data from 2011 DOE Life-Cycle Cost and Payback analysis, Table 8.3.1. IQ Incremental costs factor in the assumption that a secondhand unit costs on average 50% of a new baseline unit, and that 1/3 of IQ participants would have purchased a unit on the secondhand market. See "IQ Appliance Calculations_IA.xls" for information.

LOADSHAPE

Loadshape RE14 – Residential Clothes Washer

Loadshape G03 – Residential Dryer

Coincidence Factor

The coincidence factor for this measure is 4.31%²⁵

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\left(\frac{(Load * IQAdj)}{CEFbase} - \frac{Load}{CEFeff} \right) * Ncycles * \%Electric \right) - PairedWasher kWhAdj + \Delta kWh_{HEAT} + \Delta kWh_{COOL}$$

Where:

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

Dryer Size	Load (lbs) ²⁶
Standard	8.45
Compact	3

IQAdj = Baseline consumption adjustment for IQ program participants to account for a portion of participants who would have utilized the secondary market²⁷
 = 1.033 if IQ, 1.0 if non-IQ

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis.²⁸ If product class unknown, assume electric, standard.

Product Class	CEFbase (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft ³)	3.11
Ventless Electric, Standard (≥ 4.4 ft ³)	3.11
Vented Electric, Compact (120V) (< 4.4 ft ³)	3.01
Ventless 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

²⁵ Developed using coincident peak information from March 2015 NEEP, “Residential Electric Clothes Dryer Baseline Study” conducted by Energy Resource Solutions.

²⁶ Based on ENERGY STAR test procedures.

²⁷ It is assumed that a second-hand unit is on average 2/3 of a measure’s EUL years old (11 years). The current Federal Standard became effective in 2015 so the previous standard is used to estimate base consumption for a second hand unit, and further increased by an estimate of 0.4% * 11 years (based on review of the refrigerator/freezer regression algorithm used in the 2.1.5 Refrigerator and Freezer Recycling measure) to account for degradation of performance over time. This second hand consumption was then weighted 1/3: 2/3 current new baseline to estimate a multiplier for IQ participants. See “IQ Appliance Calculations_IA.xls” for information.

²⁸ ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

Product Class	CEFbase (lbs/kWh)
Vented Gas	2.84 ²⁹

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

Product Class	CEFeff (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
Full Heat Pump, Standard	10.40 ³¹
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 ³²

Ncycles = Number of dryer cycles per year. Use actual data if available.

If unknown, use 250 cycles per year.³³

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 16% for gas dryers³⁴

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)³⁵

Product Class	PairedWasherAdj (kWh)
Vented Electric, Standard (≥ 4.4 ft ³)	51.6
Ventless Electric, Standard (≥ 4.4 ft ³)	51.6
Most Efficient Vented Hybrid, Standard	51.6
Most Efficient Ventless Hybrid, Standard	51.6
Full Heat Pump, Standard	51.6

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

³⁰ ENERGY STAR Clothes Dryers Key Product Criteria.

³¹ 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.

³² Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

³³ 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. 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. See "ENERGY STAR Dryer Specification NEEA Amended comments Mar 16, 2013, Page 7."

³⁴ %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 sheet '6. Consumer Savings' within the aforementioned xlsx file for details.

³⁵ Dryer savings are calculated using the Clothes Washer measure. See Dryer Analysis file for more details.

Product Class	PairedWasherAdj (kWh)
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

ΔkWh_{HEAT} = Electric space heating impact due to waste heat either being predominately vented to outside or remaining in the home (ventless hybrid or heat pump)

$$= kWh_{HEATEff} - kWh_{HEATBase}$$

$$kWh_{HEAT} = \frac{(\%HeatSpace * HF * \%ElecHeat * \%Conditioned * \text{Dryer Consumption})}{COP_{HEAT}}$$

Where:

$\%HeatSpace$ = Proportion of dryer heat energy remaining in space

Vented = 5%³⁶

Ventless = 100%

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

= 58.9% for unit in heated space or unknown³⁷

= 0% for unit in unheated space

$\%ElecHeat$ = Percentage of home with electric heat

Heating Fuel	$\%ElecHeat$
Electric	100%
Fossil Fuel	0%
Unknown	24% ³⁸

$\%Conditioned$ = Portion of homes with dryer in conditioned space

= 73%³⁹

Dryer Consumption = (Load * IQAdj)/CEF * Ncycles

COP_{HEAT} = Coefficient of Performance of electric space heating

system

= Actual system efficiency including duct loss – If not available, use:⁴⁰

³⁶ Professional judgement estimate.

³⁷ Calculated 215 days where HDD 60>0, then divided by 365. NCDC US Climate Hourly Normals 15-year data set (2006-2020).

³⁸ Based on ResStock data for the state of Iowa.

³⁹ NEEP Study found 16 of 22 sites had the dryer in a heated space; NEEP, Energy & Resource Solutions "Electric Dryer Baseline Research", p8.

⁴⁰ 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	HSPF2 Estimate	COP _{HEAT} (Effective COP Estimate) (HSPF2/3.412)*0.85
Heat Pump	Before 2006	5.78 (6.8 HSPF)	1.44
	2006 – 2014	6.54 (7.7 HSPF)	1.63
	2015 on	7.5 (8.2 HSPF)	1.9
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.2 ⁴¹

$\Delta\text{kWhCOOL}$ = Cooling impact due to waste heat either being predominately vented to outside or remaining in the home (ventless hybrid or heat pump)

$$= \text{kWhCOOL}_{\text{Base}} - \text{kWhCOOL}_{\text{Eff}}$$

$$\text{kWhCOOL} = (\% \text{HeatSpace} * \text{CoolF} * \% \text{Cool} * \% \text{Conditioned} * \text{Dryer Consumption}) / \text{COP}_{\text{cool}}$$

Where:

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

= 35.1% for unit in cooled space or unknown ⁴²

= 0% for unit in uncooled space

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91% ⁴³

COP_{cool} = Coefficient of Performance of cooling system

= Actual – If not available, assume 2.79⁴⁴

Using defaults provided above, for non-IQ participants:

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 ($\geq 4.4 \text{ ft}^3$)	3.11	3.93	679.3	537.5	51.6	2.9	2.3	2.8	2.2	0.0	90.1
Ventless Electric, Standard ($\geq 4.4 \text{ ft}^3$)	3.11	3.93	679.3	537.5	51.6	58.4	46.2	56.6	44.8	-0.4	89.8

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.

⁴¹ Using the current federal standard of 8.2 HSPF for Central ASHP and averaged with electric resistance COP_{heat}, weighted based on ResStock data for the state of Iowa.

⁴² Calculated 128 days where CDD $65 > 0$, divided by 365. NCDC US Climate Hourly Normals 15-year data set (2006-2020).

⁴³ Based on ResStock data for the state of Iowa.

⁴⁴ The federal standard between 2015-2022 is used to estimate the average existing efficiencies; 14 SEER (13.3 SEER2) for Central ASHP and 11.56 SEER (10.982 SEER2) for Baseline Central AC Equipment, weighted based on ResStock data for the state of Iowa. Please see HPWH Analysis file for further details. An 85% distribution efficiency is then applied to account for duct losses.

Iowa Energy Efficiency Statewide Technical Reference Manual—2.1.2 Clothes Dryer

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	679.3	537.5	51.6	2.9	2.3	2.8	2.2	0.0	90.1
Most Efficient Vented Hybrid, Standard	3.11	4.3	679.3	491.3	51.6	2.9	2.1	2.8	2.0	0.0	136.4
Most Efficient Ventless Hybrid, Standard	3.11	4.3	679.3	491.3	51.6	58.4	42.2	56.6	40.9	-0.5	135.9
Full Heat Pump, Standard	3.11	10.4	679.3	203.1	51.6	2.9	0.9	2.8	0.8	-0.1	424.5
Vented Electric, Compact (120V) (< 4.4 ft³)	3.01	3.8	249.2	197.4	0.0	1.1	0.8	1.0	0.8	0.0	51.8
Ventless Electric, Compact (120V) (< 4.4 ft³)	3.01	3.8	249.2	197.4	0.0	21.4	17.0	20.8	16.4	-0.1	51.7
Vented Electric, Compact (240V) (< 4.4 ft³)	2.73	3.45	274.7	217.4	0.0	1.2	0.9	1.1	0.9	0.0	57.3
Ventless Electric, Compact (240V) (< 4.4 ft³)	2.13	2.68	352.1	279.9	0.0	30.3	24.1	29.3	23.3	-0.2	72.1
Vented Gas	2.84	3.48	119.0	97.1	0.0	3.2	2.6	3.1	2.5	0.0	21.9

Using defaults provided above, for IQ participants:

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	701.7	537.5	51.6	3.0	2.3	2.9	2.2	0.0	112.5
Ventless Electric, Standard (≥ 4.4 ft³)	3.11	3.93	701.7	537.5	51.6	60.3	46.2	58.5	44.8	-0.4	112.1
Most Efficient Vented Hybrid, Standard	3.11	4.3	701.7	491.3	51.6	3.0	2.1	2.9	2.0	0.0	158.8
Most Efficient Ventless Hybrid, Standard	3.11	4.3	701.7	491.3	51.6	60.3	42.2	58.5	40.9	-0.6	158.3
Full Heat Pump, Standard	3.11	10.4	701.7	203.1	51.6	3.0	0.9	2.9	0.8	-0.1	498.5
Vented Electric, Compact (120V) (< 4.4 ft³)	3.01	3.8	257.4	197.4	0.0	1.1	0.8	1.1	0.8	0.0	60.0
Ventless Electric, Compact (120V) (< 4.4 ft³)	3.01	3.8	257.4	197.4	0.0	22.1	17.0	21.4	16.4	-0.2	59.9

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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	701.7	537.5	51.6	3.0	2.3	2.9	2.2	0.0	112.5
Vented Electric, Compact (240V) (< 4.4 ft³)	2.73	3.45	283.8	217.4	0.0	1.2	0.9	1.2	0.9	0.0	66.4
Ventless Electric, Compact (240V) (< 4.4 ft³)	2.13	2.68	363.7	279.9	0.0	31.3	24.1	30.3	23.3	-0.2	83.7
Vented Gas	2.84	3.48	122.9	97.1	0.0	3.3	2.6	3.2	2.5	0.0	25.8

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.⁴⁵

CF = Summer Peak Coincidence Factor for measure
=4.31%⁴⁶

Using defaults provided above:

Product Class	ΔkW	
	Non-IQ	IQ
Vented Electric, Standard (≥ 4.4 ft³)	0.0194	0.0243
Ventless Electric, Standard (≥ 4.4 ft³)	0.0193	0.0242
Most Efficient Vented Hybrid, Standard	0.0294	0.0342
Most Efficient Ventless Hybrid, Standard	0.0293	0.0341
Full Heat Pump, Standard	0.0915	0.1074
Vented Electric, Compact (120V) (< 4.4 ft³)	0.0112	0.0129
Ventless Electric, Compact (120V) (< 4.4 ft³)	0.0111	0.0129
Vented Electric, Compact (240V) (< 4.4 ft³)	0.0124	0.0143
Ventless Electric, Compact (240V) (< 4.4 ft³)	0.0155	0.0180
Vented Gas	0.0047	0.0056

NATURAL GAS SAVINGS

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

⁴⁵ 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.

⁴⁶ Developed using coincident peak information from March 2015 NEEP, “Residential Electric Clothes Dryer Baseline Study” conducted by Energy Resource Solutions.

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

Where:

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

%Gas = Percent of overall savings coming from gas

= 0% for electric units

= 84% for gas units⁴⁷

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	1.76

$\Delta ThermHEAT$ = 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 = $(\%HeatSpace * HF * \%GasHeat * \%Conditioned * \text{Dryer Consumption}) / \eta_{HeatGas}$

Where:

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	75% ⁴⁸

Dryer Consumption = $(Load * IQAdj) / CEF * Ncycles * Therm_convert$

$\eta_{HeatGas}$ = Efficiency of heating system

⁴⁷ %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 xlsx file for details.

⁴⁸ Based on NREL ResStock data for the state of Iowa.

=74%⁴⁹

Using defaults provided above, for non-IQ participants:

Product Class	CEF base	CEFeff	Base Dryer Consumption (Therms)	Eff Dryer Consumption (Therms)	Paired Washer Therm Adj	Therm HEAT Base	Therm HEAT Eff	Total Waste Heat Impact	ΔTherm
Vented Electric, Standard (≥ 4.4 ft ³)	N/A					0.50	0.40	-0.11	-0.11
Ventless Electric, Standard (≥ 4.4 ft ³)						10.10	7.99	-2.11	-2.11
Most Efficient Vented Hybrid, Standard						0.50	0.37	-0.14	-0.14
Most Efficient Ventless Hybrid, Standard						10.10	7.30	-2.80	-2.80
Full Heat Pump, Standard						10.10	3.02	-7.08	-7.08
Vented Electric, Compact (120V) (< 4.4 ft ³)						0.19	0.15	-0.04	-0.04
Ventless Electric, Compact (120V) (< 4.4 ft ³)						3.70	2.93	-0.77	-0.77
Vented Electric, Compact (240V) (< 4.4 ft ³)						0.20	0.16	-0.04	-0.04
Ventless Electric, Compact (240V) (< 4.4 ft ³)						5.24	4.16	-1.07	-1.07
Vented Gas	2.84	3.48	21.33	17.40	1.76	0.55	0.45	-0.10	2.06

Using defaults provided above, for IQ participants:

Product Class	CEF base	CEF eff	Base Dryer Consumption (Therms)	Eff Dryer Consumption (Therms)	Paired Washer Therm Adj	Therm HEAT Base	Therm HEAT Eff	Total Waste Heat Impact	ΔTherm
Vented Electric, Standard (≥ 4.4 ft ³)	N/A					0.52	0.40	-0.12	-0.12

⁴⁹ This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 43% of Iowa homes - based on NREL ResStock Data, accessed 2023). 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: $((0.60 \times 0.92) + (0.40 \times 0.8)) \times (1 - 0.15) = 0.74$.

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Ventless Electric, Standard (≥ 4.4 ft ³)						10.43	7.99	-2.44	-2.44
Most Efficient Vented Hybrid, Standard						0.52	0.37	-0.16	-0.16
Most Efficient Ventless Hybrid, Standard						10.43	7.30	-3.13	-3.13
Full Heat Pump, Standard						10.43	3.02	-7.41	-7.41
Vented Electric, Compact (120V) (< 4.4 ft ³)						0.19	0.15	-0.04	-0.04
Ventless Electric, Compact (120V) (< 4.4 ft ³)						3.83	2.93	-0.89	-0.89
Vented Electric, Compact (240V) (< 4.4 ft ³)						0.21	0.16	-0.05	-0.05
Ventless Electric, Compact (240V) (< 4.4 ft ³)						5.41	4.16	-1.25	-1.25
Vented Gas	2.84	3.48	24.91	19.68	1.76	0.57	0.45	-0.12	3.35

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:

$$\Delta PeakTherms = \frac{\Delta Therms}{365}$$

Where:

$\Delta Therms$ = Therm impact calculated above

365 = Days per year

Product Class	$\Delta Peak$ Therms	
	Non-IQ	IQ
Vented Electric, Standard (≥ 4.4 ft ³)	-0.0003	-0.0003
Ventless Electric, Standard (≥ 4.4 ft ³)	-0.0058	-0.0067
Most Efficient Vented Hybrid, Standard	-0.0004	-0.0004
Most Efficient Ventless Hybrid, Standard	-0.0077	-0.0086
Full Heat Pump, Standard	-0.0194	-0.0203
Vented Electric, Compact (120V) (< 4.4 ft ³)	-0.0001	-0.0001
Ventless Electric, Compact (120V) (< 4.4 ft ³)	-0.0021	-0.0024
Vented Electric, Compact (240V) (< 4.4 ft ³)	-0.0001	-0.0001
Ventless Electric, Compact (240V) (< 4.4 ft ³)	-0.0029	-0.0034
Vented Gas	0.0056	0.0092

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESDR-V09-270101

SUNSET DATE: 1/1/2028

2.1.3 Refrigerator

DESCRIPTION

A refrigerator meeting either ENERGY STAR⁵⁰/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 years⁵¹

DEEMED MEASURE COST

The full cost of a baseline unit is \$803.⁵²

The non-IQ participants, the incremental cost to the Energy Star level is \$12, to CEE Tier 2 level is \$21 and to CEE Tier 3 is \$59.⁵³ For IQ participants the incremental cost is assumed to be \$146 for an ENERGY STAR unit, \$155 for a CEE Tier 2 unit and \$193 for a CEE Tier 3 unit.⁵⁴

LOADSHAPE

Loadshape RE16 – Residential Refrigeration

⁵⁰ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁵¹ Mean from Figure 8.2.3, DOE, 2011-08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers.

⁵² 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.

⁵³ 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.

⁵⁴ IQ Incremental costs factor in the assumption that a secondhand unit costs on average 50% of a new baseline unit, and that 1/3 of IQ participants would have purchased a unit on the secondhand market. See "IQ Appliance Calculations_IA.xls" for information.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

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

Where:

kWh_{base} = Baseline consumption

= Based on average consumption of non-ENERGY STAR units available in 4 main product classes. See tables below.⁵⁵

$IQAdj$ = Baseline consumption adjustment for IQ program participants to account for a portion of participants who would have utilized the secondary market.⁵⁶

= 1.0 if non-IQ, if IQ:

Product Class	IQAdj
Top Freezer (PC 3)	1.083
Side-by-Side w/ TTD (PC 7)	1.026
Bottom Freezer (PC 5)	1.033
Bottom Freezer w/ TTD (PC 5A)	1.044
Weighted Average	1.059

$\%Savings$ = 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).

⁵⁵ See 'Refrig_CAC database_04012022.XLS' for more information.

⁵⁶ It is assumed that a second-hand unit is on average 2/3 of a measure's EUL years old (11 years). The current Federal Standard became effective in 2014 so the previous standard is used to estimate base consumption for a second hand unit, and further increased by an estimate of 0.4% * 11 years (based on review of the refrigerator/freezer regression algorithm used in the 2.1.5 Refrigerator and Freezer Recycling measure) to account for degradation of performance over time. This second hand consumption was then weighted 1/3: 2/3 current new baseline to estimate a multiplier for IQ participants. See "IQ Appliance Calculations_IA.xls" for information.

$$= - (HF / COP_{\text{Heat-Electric}}) * \%ElecHeat$$

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

= 58.9% for unit in heated space or unknown⁵⁷

= 0% for unit in unheated space

$COP_{\text{Heat-Electric}}$ = Efficiency in COP of Heating equipment

= Actual system efficiency including duct loss – If not available, use:⁵⁸

System Type	Age of Equipment	HSPF2 Estimate	$COP_{\text{Heat-Electric}}$ (Effective COP Estimate) (HSPF2/3.412)*0.85
Heat Pump	Before 2006	5.78 (6.8 HSPF)	1.44
	2006 – 2014	6.54 (7.7 HSPF)	1.63
	2015 on	7.5 (8.2 HSPF)	1.9
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.2 ⁵⁹

$\%ElecHeat$ = Percentage of home with electric heat

Heating Fuel	$\%ElecHeat$
Electric	100%
Fossil Fuel	0%
Unknown	24% ⁶⁰

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

$$= (CoolF / COP_{\text{Cool}}) * \%Cool$$

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

= 35.1% for unit in cooled space or unknown⁶¹

= 0% for unit in uncooled space

COP_{Cool} = Coefficient of Performance of cooling system

= Actual – If not available, assume 2.79 COP⁶²

⁵⁷ Calculated 215 days where HDD 60>0, then divided by 365. NCDC US Climate Hourly Normals 15-year data set (2006-2020).

⁵⁸ 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.

⁵⁹ Using the current federal standard of 8.2 HSPF for Central ASHP and averaged with electric resistance COPheat, weighted based on ResStock data for the state of Iowa.

⁶⁰ Based on ResStock data for the state of Iowa.

⁶¹ Calculated 128 days where CDD 65>0, divided by 365. NCDC US Climate Hourly Normals 15-year data set (2006-2020).

⁶² The federal standard between 2015-2022 is used to estimate the average existing efficiencies; 14 SEER (13.3 SEER2) for Central ASHP and 11.56 SEER (10.982 SEER2) for Baseline Central AC Equipment, weighted based on ResStock data for the state of Iowa. Please see HPWH Analysis file for further details. An 85% distribution efficiency is then applied to account for duct losses.

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%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91% ⁶³

Default assumptions are provided below:

Market	Product Class	Baseline Usage kWh _{base}	Unit ΔkWh			ΔkWh _{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
Non-IQ	Top Freezer (PC 3)	472.1	47.2	70.8	94.4	-0.17	-0.26	-0.34	47.0	70.6	94.1
	Side-by-Side w/ TTD (PC 7)	707.8	70.8	106.2	141.6	-0.26	-0.39	-0.52	70.5	105.8	141.0
	Bottom Freezer (PC 5)	551.8	55.2	82.8	110.4	-0.20	-0.30	-0.40	55.0	82.5	110.0
	Bottom Freezer w/ TTD (PC 5A)	656.9	65.7	98.5	131.4	-0.24	-0.36	-0.48	65.5	98.2	130.9
IQ	Top Freezer (PC 3)	511.1	86.2	109.9	133.5	-0.31	-0.40	-0.49	85.9	109.4	133.0
	Side-by-Side w/ TTD (PC 7)	726.2	89.1	124.5	159.9	-0.32	-0.45	-0.58	88.8	124.1	159.3
	Bottom Freezer (PC 5)	569.9	73.3	100.9	128.4	-0.27	-0.37	-0.47	73.0	100.5	128.0
	Bottom Freezer w/ TTD (PC 5A)	685.6	94.3	127.2	160.0	-0.34	-0.46	-0.58	94.0	126.7	159.4

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:

Market	Product Class	Market Weight ⁶⁴	Total ΔkWh			ΔkWh _{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
Non - IQ	Top Freezer (PC 3)	52%	55.8	83.8	111.7	0.2	0.2	0.3	56.0	84.0	112.0
	Side-by-Side w/ TTD (PC 7)	22%									
	Bottom Freezer (PC 5)	13%									
	Bottom Freezer w/ TTD (PC 5A)	13%									
IQ	Top Freezer (PC 3)	52%	86.2	114.2	142.1	0.2	0.3	0.4	86.5	114.5	142.5
	Side-by-Side w/	22%									

⁶³ Based on ResStock data for the state of Iowa.

⁶⁴ Personal Communication from Melisa Fiffer, ENERGY STAR Appliance Program Manager, EPA 10/26/14

Iowa Energy Efficiency Statewide Technical Reference Manual—2.1.3 Refrigerator

Market	Product Class	Market Weight ⁶⁴	Total ΔkWh			ΔkWh _{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
	TTD (PC 7)										
	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 ΔkWh_{wasteheat})

HOURS = Equivalent Full Load Hours
= 5280⁶⁵

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

Refrigerator Location	WHFdCool
Cooled space	1.22 ⁶⁶
Uncooled	1.0
Unknown	1.2 ⁶⁷

CF = Summer Peak Coincident Factor
= 70.9%⁶⁸

Default assumptions are provided below:

Market	Product Class	ΔkW		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Non - IQ	Top Freezer (PC 3)	0.0076	0.0114	0.0152
	Side-by-Side w/ TTD (PC 7)	0.0114	0.0170	0.0227
	Bottom Freezer (PC 5)	0.0089	0.0133	0.0177
	Bottom Freezer w/ TTD (PC 5A)	0.0105	0.0158	0.0211
IQ	Top Freezer (PC 3)	0.0138	0.0176	0.0214

⁶⁵ Based on analysis of loadshape data provided by Cadmus.

⁶⁶ 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.

⁶⁷ The value is estimated at 1.2 (calculated as 1 + (0.91 * 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 91% is the percentage of homes have central cooling (based on ResStock data for the state of Iowa).

⁶⁸ Based on analysis of loadshape data provided by Cadmus.

Market	Product Class	ΔkW		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
	Side-by-Side w/ TTD (PC 7)	0.0143	0.0200	0.0257
	Bottom Freezer (PC 5)	0.0118	0.0162	0.0206
	Bottom Freezer w/ TTD (PC 5A)	0.0151	0.0204	0.0257

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:

Market	Product Class	Market Weight ⁶⁹	ΔkW		
			Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Non - IQ	Top Freezer (PC 3)	52%	0.0090	0.0134	0.0179
	Side-by-Side w/ TTD (PC 7)	22%			
	Bottom Freezer (PC 5)	13%			
	Bottom Freezer w/ TTD (PC 5A)	13%			
IQ	Top Freezer (PC 3)	52%	0.0138	0.0183	0.0228
	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
	= $-(HF / COP_{Heat-Gas}) * \%GasHeat$
HF	= Heating Factor or percentage of reduced waste heat that must now be heated
	= 58.9% for unit in heated space or unknown ⁷⁰
	= 0% for unit in unheated space
$COP_{Heat-Gas}$	= Efficiency of heating system
	= 74% ⁷¹

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

⁷⁰ Based on 215 days where HDD 60>0, divided by 365. NCDC US Climate Normals 15-year data set (2006-2020) for Des Moines. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷¹ 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

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	75% ⁷²

0.03412 = Converts kWh to Therms

Default assumptions are provided below:

Market	Product Class	DTherms		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Non - IQ	Top Freezer (PC 3)	-0.96	-1.44	-1.92
	Side-by-Side w/ TTD (PC 7)	-1.44	-2.16	-2.88
	Bottom Freezer (PC 5)	-1.12	-1.69	-2.25
	Bottom Freezer w/ TTD (PC 5A)	-1.34	-2.01	-2.68
IQ	Top Freezer (PC 3)	-1.76	-2.24	-2.72
	Side-by-Side w/ TTD (PC 7)	-1.82	-2.54	-3.26
	Bottom Freezer (PC 5)	-1.49	-2.05	-2.62
	Bottom Freezer w/ TTD (PC 5A)	-1.92	-2.59	-3.26

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:

Market	Product Class	Market Weight ⁷³	ΔTherms		
			Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Non - IQ	Top Freezer (PC 3)	52%	-1.14	-1.71	-2.27
	Side-by-Side w/ TTD (PC 7)	22%			
	Bottom Freezer (PC 5)	13%			
	Bottom Freezer w/ TTD (PC 5A)	13%			
IQ	Top Freezer (PC 3)	52%	-1.76	-2.33	-2.89
	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:

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

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: $((0.60 \times 0.92) + (0.40 \times 0.8)) \times (1 - 0.15) = 0.74$.

⁷² Based on NREL ResStock data for the state of Iowa.

⁷³ Personal Communication from Melisa Fiffer, ENERGY STAR Appliance Program Manager, EPA 10/26/14

Where:

Δ Therms = Therm impact calculated above
 HeatDays = Heat season days per year
 = 215⁷⁴

Default assumptions are provided below:

Market	Product Class	Δ PeakTherms		
		Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Non - IQ	Top Freezer (PC 3)	-0.0045	-0.0067	-0.0089
	Side-by-Side w/ TTD (PC 7)	-0.0067	-0.0101	-0.0134
	Bottom Freezer (PC 5)	-0.0052	-0.0078	-0.0105
	Bottom Freezer w/ TTD (PC 5A)	-0.0062	-0.0093	-0.0124
IQ	Top Freezer (PC 3)	-0.0082	-0.0104	-0.0126
	Side-by-Side w/ TTD (PC 7)	-0.0084	-0.0118	-0.0151
	Bottom Freezer (PC 5)	-0.0069	-0.0096	-0.0122
	Bottom Freezer w/ TTD (PC 5A)	-0.0089	-0.0120	-0.0152

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:

Market	Product Class	Market Weight ⁷⁵	Δ PeakTherms		
			Energy Star/ CEE Tier 1	CEE Tier 2	CEE Tier 3
Non - IQ	Top Freezer (PC 3)	52%	-0.0053	-0.0079	-0.0106
	Side-by-Side w/ TTD (PC 7)	22%			
	Bottom Freezer (PC 5)	13%			
	Bottom Freezer w/ TTD (PC 5A)	13%			
IQ	Top Freezer (PC 3)	52%	-0.0082	-0.0108	-0.0135
	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-V06-270101

SUNSET DATE: 1/1/2030

⁷⁴ Calculated number of days where HDD 60 > 0. NCDC US Climate Hourly Normals 15-year data set (2006-2020) for Des Moines. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷⁵ 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 STAR⁷⁶ 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 $1.73 \times \text{Total Volume}$):

Product Category	Volume (cubic feet)	Federal Baseline Maximum Energy Usage in kWh/year ⁷⁷	ENERGY STAR Maximum Energy Usage in kWh/year ⁷⁸
Upright Freezers with Manual Defrost	7.75 or greater	$5.57 \times \text{AV} + 193.7$	$5.01 \times \text{AV} + 174.3$
Upright Freezers with Automatic Defrost without an automatic icemaker	7.75 or greater	$8.62 \times \text{AV} + 228.3$	$7.76 \times \text{AV} + 205.5$
Upright Freezers with Automatic Defrost with an automatic icemaker	7.75 or greater	$8.62 \times \text{AV} + 312.3$	$7.76 \times \text{AV} + 289.5$
Built-In Upright freezers with automatic defrost without an automatic icemaker	7.75 or greater	$9.86 \times \text{AV} + 260.9$	$8.87 \times \text{AV} + 234.8$
Built-In Upright freezers with automatic defrost with an automatic icemaker	7.75 or greater	$9.86 \times \text{AV} + 344.9$	$8.87 \times \text{AV} + 318.8$
Chest Freezers and all other Freezers except Compact Freezers	7.75 or greater	$7.29 \times \text{AV} + 107.8$	$6.56 \times \text{AV} + 97.0$
Chest Freezers with automatic defrost	7.75 or greater	$10.24 \times \text{AV} + 148.1$	$9.22 \times \text{AV} + 133.3$
Compact Upright Freezers with Manual Defrost	< 7.75 and 36 inches or less in height	$8.65 \times \text{AV} + 225.7$	$7.79 \times \text{AV} + 203.1$
Compact Upright Freezers with Automatic Defrost	< 7.75 and 36 inches or less in height	$10.17 \times \text{AV} + 351.9$	$9.15 \times \text{AV} + 316.7$
Compact Chest Freezers	< 7.75 and 36 inches or less in height	$9.25 \times \text{AV} + 136.8$	$8.33 \times \text{AV} + 123.1$

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.

⁷⁶ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁷⁷ Code of Federal Regulations, Appliance and Equipment Standards (10 CFR 430.32(a)), applying to products manufactured starting on September 15, 2014

⁷⁸ ENERGY STAR Program Requirements Product Specification for Consumer Refrigeration Products, v5.1, effective September 15, 2014

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 21 years for standard sized units and 10 years for compact units.⁷⁹

DEEMED MEASURE COST

The incremental cost for this measure is \$4⁸⁰ for non-IQ participants and \$104 for IQ participants.⁸¹

LOADSHAPE

Loadshape RE15 – Residential Freezer

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh_{Unit} = (kWh_{BASE} * IQAdj) - kWh_{ESTAR}$$

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.
- $IQAdj$ = Baseline consumption adjustment for IQ program participants to account for a portion of participants who would have utilized the secondary market.⁸²
 = 1.0 if non-IQ, if IQ:

Product Category	IQAdj
Upright Freezers	1.08
Chest Freezers	1.09
Compact Upright Freezers	1.08
Compact Chest Freezers	1.06
Weighted Average	1.08

- kWh_{ESTAR} = ENERGY STAR kWh consumption per year

⁷⁹ Measure life is sourced from 2021 DOE Rulemaking Technical Support Document, “Refrigerator, Refrigerator-Freezer, and Freezer Life-Cycle Cost (LCC) Analysis Spreadsheet”, November 2021.

⁸⁰ Incremental measure costs are estimated using the 2021 DOE Rulemaking Technical Support Document, “Refrigerator, Refrigerator-Freezer, and Freezer Life-Cycle Cost (LCC) Analysis Spreadsheet,” November 2021 and weighting using ENERGY STAR Freezer Qualified Products List (QPL) as accessed on 4/11/2023. Install cost data was trended to provide estimates at the efficiency levels specified.

⁸¹ IQ Incremental costs factor in the assumption that a secondhand unit costs on average 50% of a new baseline unit, and that 1/3 of IQ participants would have purchased a unit on the secondhand market. See “IQ Appliance Calculations_IA.xls” for information.

⁸² It is assumed that a second-hand unit is on average 2/3 of a measure’s EUL years old (14 years). The current Federal Standard became effective in 2014 so the previous standard is used to estimate base consumption for a secondhand unit, and further increased by an estimate of 0.4% * 14 years (based on review of the refrigerator/freezer regression algorithm used in the 2.1.5 Refrigerator and Freezer Recycling measure) to account for degradation of performance over time. This secondhand consumption was then weighted 1/3: 2/3 new baseline to estimate a multiplier for IQ participants. See “IQ Appliance Calculations_IA.xls” for information.

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 / COP _{Heat-Electric}) * %ElecHeat
HF	= Heating Factor or percentage of reduced waste heat that must now be heated = 58.9% for unit in heated space or unknown ⁸³ = 0% for unit in unheated space
COP _{Heat-Electric}	= Efficiency in COP of Heating equipment = Actual system efficiency including duct loss – If not available, use: ⁸⁴

System Type	Age of Equipment	HSPF2 Estimate	COP _{Heat-Electric} (Effective COP Estimate) (HSPF2/3.412)*0.85
Heat Pump	Before 2006	5.78 (6.8 HSPF)	1.44
	2006 – 2014	6.54 (7.7 HSPF)	1.63
	2015 on	7.5 (8.2 HSPF)	1.9
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.2 ⁸⁵

%ElecHeat = Percentage of home with electric heat

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	24% ⁸⁶

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

$$= (CoolF / COP_{Cool}) * \%Cool$$

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

⁸³ Calculated 215 days where HDD 60>0, then divided by 365. NCDC US Climate Hourly Normals 15-year data set (2006-2020).

⁸⁴ 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.

⁸⁵ Using the current federal standard of 8.2 HSPF for Central ASHP and averaged with electric resistance COPheat, weighted based on ResStock data for the state of Iowa.

⁸⁶ Based on ResStock data for the state of Iowa.

= 35.1% for unit in cooled space or unknown⁸⁷

= 0% for unit in uncooled space

COP_{Cool} = Coefficient of Performance of cooling system

= Actual – If not available, assume 2.79 COP⁸⁸

%Cool = Percentage of home with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91% ⁸⁹

Default assumptions are provided below:

Market	Product Category	kWh _{BASE}	kWh _{ESTAR}	Unit kWh Savings	ΔkWh _{WasteHeat}	Total ΔkWh
Non-IQ	Upright Freezers	494.1	423.0	71.1	-0.26	70.9
	Chest Freezers	248.3	195.2	53.1	-0.19	52.9
	Compact Upright Freezers	326.3	225.9	100.4	-0.37	100.0
	Compact Chest Freezers	190.0	159.9	30.1	-0.11	30.0
IQ	Upright Freezers	531.6	423.0	108.7	-0.40	108.3
	Chest Freezers	270.2	195.2	75.0	-0.27	74.7
	Compact Upright Freezers	352.6	225.9	126.7	-0.46	126.2
	Compact Chest Freezers	202.0	159.9	42.1	-0.15	42.0

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

Market	Product Class	Market Weight ⁹⁰	Unit kWh Savings	ΔkWh _{WasteHeat}	Total ΔkWh
Non-IQ	Upright Freezer	55%	62.8	-0.23	62.6
	Chest Freezer	32%			
	Compact Upright Freezer	4%			
	Compact Chest Freezer	9%			
IQ	Upright Freezer	55%	92.6	-0.34	92.3
	Chest Freezer	32%			
	Compact Upright Freezer	4%			
	Compact Chest Freezer	9%			

⁸⁷ Calculated 128 days where CDD 65>0, divided by 365. NCDC US Climate Hourly Normals 15-year data set (2006-2020).

⁸⁸ The federal standard between 2015-2022 is used to estimate the average existing efficiencies; 14 SEER (13.3 SEER2) for Central ASHP and 11.56 SEER (10.982 SEER2) for Baseline Central AC Equipment, weighted based on ResStock data for the state of Iowa. Please see HPWH Analysis file for further details. An 85% distribution efficiency is then applied to account for duct losses.

⁸⁹ Based on ResStock data for the state of Iowa.

⁹⁰ Weighted based on numbers of models available in the California Energy Commission Appliance Efficiency Program.

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
= 5,895⁹¹

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

Freezer Location	WHFdCool
Cooled space	1.22 ⁹²
Uncooled	1.0
Unknown	1.2 ⁹³

CF = Summer Peak Coincident Factor
= 95.3%⁹⁴

Default assumptions are provided below:

Product Category	kW Savings	
	Non-IQ	IQ
Upright Freezers	0.0138	0.0211
Chest Freezers	0.0103	0.0145
Compact Upright Freezers	0.0195	0.0246
Compact Chest Freezers	0.0058	0.0082

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 ⁹⁵	kW Savings	
		Non-IQ	IQ
Upright Freezer	55%	0.0122	0.0180
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,

⁹¹ Based on analysis of loadshape data provided by Cadmus.

⁹² 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.

⁹³ The value is estimated at 1.2 (calculated as $1 + (0.91 * 0.61 / 2.8)$). 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 91% is the percentage of homes have central cooling (based on ResStock data for the state of Iowa).

⁹⁴ Based on analysis of loadshape data provided by Cadmus.

⁹⁵ Weighted based on numbers of models available in the California Energy Commission Appliance Efficiency Program.

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 / $COP_{Heat-Gas}$) * %GasHeat
- HF = Heating Factor or percentage of reduced waste heat that must now be heated
- = 58.9% for unit in heated space or unknown⁹⁶
- = 0% for unit in unheated space
- $COP_{Heat-Gas}$ = Efficiency of heating system
- = 74%⁹⁷
- %GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	75% ⁹⁸

0.03412 = Converts kWh to Therms

Default assumptions are provided below:

Product Category	$\Delta Therms$	
	Non-IQ	IQ
Upright Freezers	-1.45	-2.21
Chest Freezers	-1.08	-1.53
Compact Upright Freezers	-2.04	-2.58
Compact Chest Freezers	-0.61	-0.86

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 ⁹⁹	$\Delta Therms$	
		Non-IQ	IQ
Upright Freezer	55%	-1.28	-1.89

⁹⁶ Based on 215 days where HDD 60>0, divided by 365. NCDC US Climate Normals 15-year data set (2006-2020) for Des Moines. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁷ 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.

⁹⁸ Based on NREL ResStock data for the state of Iowa.

⁹⁹ Weighted based on numbers of models available in the California Energy Commission Appliance Efficiency Program.

Product Class	Market Weight ⁹⁹	ΔTherms	
		Non-IQ	IQ
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

= 215¹⁰⁰

Default assumptions are provided below:

Product Category	ΔPeakTherms	
	Non-IQ	IQ
Upright Freezers	-0.0067	-0.0103
Chest Freezers	-0.0050	-0.0071
Compact Upright Freezers	-0.0095	-0.0120
Compact Chest Freezers	-0.0029	-0.0040

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 ¹⁰¹	ΔPeakTherms	
		Non-IQ	IQ
Upright Freezer	55%	-0.0059	-0.0087
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

¹⁰⁰ Calculated number of days where HDD 60 > 0. NCDC U.S. Climate Hourly Normals 15-year data set (2006-2020) for Des Moines. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹⁰¹ Weighted based on numbers of models available in the California Energy Commission Appliance Efficiency Program.

MEASURE CODE: RS-APL-ESFR-V05-270101

SUNSET DATE: 1/1/2030

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 applying program data from MidAmerican and Alliant from 2019 and 2020 to the regression equation.

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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated remaining useful life of the recycling units is 6.5 years.¹⁰²

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 \$100 per unit.¹⁰³

LOADSHAPE

Loadshape RE16 – Residential Refrigerator

Loadshape RE15 – Residential Freezer

¹⁰² 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 determine 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.

¹⁰³ Based on program costs provided by Mid American and Alliant Energy in 2021.

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

Regression analysis: Refrigerators

Energy savings for refrigerators are based upon a linear regression model using the following coefficients:¹⁰⁴

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	15.366
Interaction: Located in Unconditioned Space x HDD/365	-11.067

$$\Delta kWh_{unit} = [83.32 + (Age * 3.68) + (Pre - 1990 * 485.04) + (Size * 27.15) + (Side - by - side * 406.78) + (Primary Usage * 161.86) + (CDD/365 * unconditioned * 15.37) + (HDD/365 * unconditioned * -11.07)] * Part Use Factor$$

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: ¹⁰⁵

Climate Zone (City Based Upon)	GHCnd ID	Official Name	CDD 65	CDD 65 / 365
Zone 5 (Burlington)	USC00131060	BURLINGTON 2S, IA US	1,105	3.03
Zone 6 (Mason City)	USW00014940	MASON CITY MUNI AP, IA US	644	1.76

¹⁰⁴ 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.

¹⁰⁵ National Climatic Data Center, Annual Normals calculated by NCDC, 15-year span from 2006-2020, with a base temp of 65°F.

Climate Zone (City Based Upon)	GHCNd ID	Official Name	CDD 65	CDD 65 / 365
Average (Des Moines) ¹⁰⁶	USW00014933	DES MOINES INTL AP, IA US	1,134	3.10

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 does not in itself imply the space is conditioned.

HDD = Heating Degree Days

= Dependent on location:¹⁰⁷

Climate Zone (City Based Upon)	GHCNd ID	Official Name	HDD 60	HDD 60 / 365
Zone 5 (Burlington)	USC00131060	BURLINGTON 2S, IA US	4,832	13.24
Zone 6 (Mason City)	USW00014940	MASON CITY MUNI AP, IA US	6,356	17.41
Average (Des Moines) ¹⁰⁸	USW00014933	DES MOINES INTL AP, IA US	5,013	13.73

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 0.91.¹⁰⁹

Deemed approach: Refrigerators

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

Where:

UEC = Unit Energy Consumption based on Mid American and Alliant 2019 and 2020 program data¹¹⁰:

Independent Variable Description	2019/2020 Program Data
Age (years)	22.7
Pre-1990 (=1 if manufactured pre-1990)	0.21
Size (cubic feet)	19.4
Dummy: Side-by-Side (= 1 if side-by-side)	0.23
Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit)	0.72
Located in Unconditioned Space	0.62

¹⁰⁶ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹⁰⁷ National Climatic Data Center, Annual Normals calculated by NCDC, 15-year span from 2006-2020, with a base temp of 60°F.

¹⁰⁸ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹⁰⁹ 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.

¹¹⁰ See IA Refrig Freezer Recycling Excel Analysis File for details.

= Dependent on climate zone as provided in table below.

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 0.91.¹¹¹

Deemed refrigerator savings are provided below:

Climate Zone (City Based Upon)	UEC	ΔkWh per Unit
Zone 5 (Burlington)	944.9	859.9
Zone 6 (Mason City)	903.9	822.6
Average (Des Moines) ¹¹²	942.2	857.4

Regression analysis; Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients:¹¹³

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	9.778
Interaction: Located in Unconditioned Space x HDD/365	-12.755

$$\Delta kWh_{unit} = [132.12 + (Age * 12.13) + (Pre - 1990 * 156.18) + (Size * 31.84) + (Chest Freezer * -19.71) + (CDD/365 * unconditioned * 9.78) + (HDD/365 * unconditioned * -12.75)] * Part Use Factor$$

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

¹¹¹ 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.

¹¹² Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹¹³ 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.

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 0.86.¹¹⁴

Deemed approach: Freezers

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

Where:

UEC = Unit Energy Consumption of retired unit based on Mid American and Alliant 2019 and 2020 program data¹¹⁵:

Independent Variable Description	2019/2020 Program Data
Age (years)	30.3
Pre-1990 (=1 if manufactured pre-1990)	0.49
Size (cubic feet)	15.7
Chest Freezer Configuration (=1 if chest freezer)	0.50
Interaction: Located in Unconditioned Space x CDD/365	0.83

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 0.86.¹¹⁶

Deemed freezer savings are provided below:

Climate Zone (City Based Upon)	UEC	ΔkWh per Unit
Zone 5 (Burlington)	950.4	817.3
Zone 6 (Mason City)	896.2	770.7
Average (Des Moines) ¹¹⁷	945.8	813.4

Additional Waste Heat Impacts

Only for retired units from conditioned spaces in the home.

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

Where:

Conditioned = % of units in conditioned space

¹¹⁴ 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.

¹¹⁵ See IA Refrig Freezer Recycling Excel Analysis File for details.

¹¹⁶ 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.

¹¹⁷ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

= 100% if unit in conditioned space, 0% if unit in unconditioned space,

= If unknown and for deemed approach assume 38% for refrigerators and 17% for freezers¹¹⁸

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).

= $-(HF / COP_{Heat-Electric}) * \%ElecHeat$

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

= 58.9% for unit in heated space or unknown¹¹⁹

= 0% for unit in unheated space

$COP_{Heat-Electric}$ = Efficiency in COP of Heating equipment

= Actual system efficiency including duct loss – If not available, use:¹²⁰

System Type	Age of Equipment	HSPF2 Estimate	$COP_{Heat-Electric}$ (Effective COP Estimate) (HSPF2/3.412)*0.85
Heat Pump	Before 2006	5.78 (6.8 HSPF)	1.44
	2006 – 2014	6.54 (7.7 HSPF)	1.63
	2015 on	7.5 (8.2 HSPF)	1.9
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.2 ¹²¹

$\%ElecHeat$ = Percentage of home with electric heat

Heating Fuel	$\%ElecHeat$
Electric	100%
Fossil Fuel	0%
Unknown	24% ¹²²

$WHFeCool$

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

= $(CoolF / COP_{Cool}) * \%Cool$

¹¹⁸ Percentage of units in conditioned space is based on Mid American and Alliant program data from 2019/2020.

¹¹⁹ Calculated 215 days where HDD 60>0, then divided by 365. NCDC US Climate Hourly Normals 15-year data set (2006-2020).

¹²⁰ 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.

¹²¹ Using the current federal standard of 8.2 HSPF for Central ASHP and averaged with electric resistance COPheat, weighted based on ResStock data for the state of Iowa.

¹²² Based on ResStock data for the state of Iowa.

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

= 35.1% for unit in cooled space or unknown¹²³

= 0% for unit in uncooled space

COP_{Cool} = Coefficient of Performance of cooling system

= Actual – If not available, assume 2.79 COP¹²⁴

%Cool = Percentage of homes with cooling

Home	%Cool
Cooling	100%
No Cooling	0%
Unknown	91% ¹²⁵

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh_{unit}}{HOURS} * (\%Cool * WHFdCool) * CF$$

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	1.22 ¹²⁶
Uncooled	1.0

CF = Coincident factor as calculated using eShapes loadprofile

Refrigerators = 70.9%

Freezers = 95.3%

¹²³ Based on 128 days where CDD 65>0, divided by 365. NCDC U.S. Climate Hourly Normals 15-year data set (2006-2020) for Des Moines. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹²⁴ The federal standard between 2015-2022 is used to estimate the average existing efficiencies; 14 SEER (13.3 SEER2) for Central ASHP and 11.56 SEER (10.982 SEER2) for Baseline Central AC Equipment, weighted based on ResStock data for the state of Iowa. Please see HPWH Analysis file for further details. An 85% distribution efficiency is then applied to account for duct losses for.

¹²⁵ Based on ResStock data for the state of Iowa.

¹²⁶ 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.

Deemed approach: Refrigerators

Climate Zone (City Based Upon)	ΔkW per Unit
Zone 5 (Burlington)	0.1282
Zone 6 (Mason City)	0.1226
Average (Des Moines) ¹²⁷	0.1278

Deemed approach: Freezers

Climate Zone (City Based Upon)	ΔkW per Unit
Zone 5 (Burlington)	0.1467
Zone 6 (Mason City)	0.1383
Average (Des Moines) ¹²⁸	0.1460

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).

$$\Delta Therms_{Wasteheat} = \text{Conditioned} * \Delta kWh_{Unit} * WHFeHeatGas * 0.03412$$

Where:

- ΔkWh_{Unit} = kWh savings calculated from either method above, not including the ΔkWh_{WasteHeat}
- WHFeHeatGas = Waste Heat Factor for Energy to account for gas heating increase from removing waste heat from refrigerator/freezer
- = - (HF / COP_{Heat-Gas}) * %GasHeat
- HF = Heating Factor or percentage of reduced waste heat that must now be heated
- = 58.9% for unit in heated space or unknown ¹²⁹
- = 0% for unit in unheated space
- COP_{Heat-Gas} = Efficiency of heating system
- = Actual, if unknown assume 74%¹³⁰

¹²⁷ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹²⁸ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹²⁹ Calculated 215 days where HDD 60>0, divided by 365. NCDC US Climate Hourly Normals 15-year data set (2006-2020) for Des Moines.

¹³⁰ 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.

%GasHeat = Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	75% ¹³¹

0.03412 = Converts kWh to Therms

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta\text{Therms}_{\text{WasteHeat}}$
Refrigerator	Zone 5 (Burlington)	-6.6
	Zone 6 (Mason City)	-6.3
	Average (Des Moines) ¹³²	-6.6
Freezer	Zone 5 (Burlington)	-2.9
	Zone 6 (Mason City)	-2.7
	Average (Des Moines) ¹³³	-2.9

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 is therefore assumed to be:

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

= 215¹³⁴

Deemed waste heat impacts are provided below:

¹³¹ Based on ResStock data for the state of Iowa.

¹³² Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹³³ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹³⁴ Calculated number of days where HDD 60 > 0. NCDC U.S. Climate Hourly Normals 15-year data set (2006-2020) for Des Moines.

Unit Type	Climate Zone (City based upon)	Δ PeakTherms
Refrigerator	Zone 5 (Burlington)	-0.0306
	Zone 6 (Mason City)	-0.0292
	Average (Des Moines) ¹³⁵	-0.0305
Freezer	Zone 5 (Burlington)	-0.0134
	Zone 6 (Mason City)	-0.0127
	Average (Des Moines) ¹³⁶	-0.0134

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-RFRC-V07-270101

SUNSET DATE: 1/1/2029

¹³⁵ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹³⁶ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

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 STAR¹³⁷ minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard. The minimum efficiency ratings are presented below¹³⁸.

Product Class (Btu/H)	Federal Standard CEERbase, with Louvered Sides, without Reverse Cycle ¹³⁹	Federal Standard CEERbase, without Louvered Sides, without Reverse Cycle	ENERGY STAR CEERee, with Louvered Sides	ENERGY STAR CEERee, without Louvered Sides	ENERGY STAR Most Efficient CEERee, with Louvered Sides	ENERGY STAR Most Efficient CEERee, without Louvered Sides
< 8,000	11.0	10.0	13.7	12.8	14.85	13.5
8,000 to 10,999	10.9	9.6	14.7	13.0	16.0	14.1
11,000 to 13,999		9.5		12.8		13.9
14,000 to 19,999	10.7	9.3	14.4	12.6		
20,000 to 24,999	9.4	9.4	12.7	12.7	13.8	13.8
25,000-27,999	9.0		12.2		13.2	
≥ 28,000						

Casement	Federal Standard CEERbase	ENERGY STAR CEERee	ENERGY STAR Most Efficient CEERee
Casement-only	9.5	12.8	13.9
Casement-slider	10.4	14.0	15.3

¹³⁷ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

¹³⁸ 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.

¹³⁹ Federal standard air conditioner baselines (Code of Federal Regulations 10 CFR 430.32(b))

Reverse Cycle - Product Class (Btu/H)	Federal Standard CEERbase, with Louvered Sides	Federal Standard CEERbase, without Louvered Sides ¹⁴⁰	ENERGY STAR CEERee, with Louvered Sides ¹⁴¹	ENERGY STAR CEERee, without Louvered Sides	ENERGY STAR Most Efficient CEERee, with Louvered Sides ¹⁴²	ENERGY STAR Most Efficient CEERee, without Louvered Sides
< 14,000	N/A	9.3	N/A	10.2	N/A	13.7
≥ 14,000	N/A	8.7	N/A	9.6	N/A	12.8
< 20,000	9.8	N/A	10.8	N/A	14.4	N/A
≥ 20,000	9.3	N/A	10.2	N/A	13.7	N/A

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR efficiency standards presented above.

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years.¹⁴³

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be \$50 for an ENERGY STAR unit¹⁴⁴ and \$260 for an ENERGY STAR Most Efficient unit.¹⁴⁵

LOADSHAPE

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

¹⁴⁰ Federal standard air conditioner baselines.

¹⁴¹ EnergyStar version 5.0 Room Air Conditioner Program Requirements.

¹⁴² ENERGY STAR 2024 Most Efficient Recognition Criteria for Room Air Conditioners.

¹⁴³ Comprehensive TRM Review MA19R17-B-TRM Final Report, submitted by Guidehouse on March 8th, 2021.

¹⁴⁴ Energy Star Room Air Conditioner Savings Calculator

¹⁴⁵ NEEP Mid-Atlantic TRM (version 9.0, October 2019) which uses hedonic models and data pulled from "2010-2012 WO017 Ex Ante Measure Cost Study", Itron, conducted on behalf of the California Public Utility Commission in 2014. For more information, please see "room-ac-analysis-2024.xls", 'ESME Costs' tab.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

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

Where:

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

= dependent on location:

Climate Zone (City Based Upon) ¹⁴⁶	Hours ¹⁴⁷
Zone 5 (Burlington)	330
Zone 6 (Mason City)	168
Average/Unknown (Des Moines)	292

Btu/H = Size of unit

= Actual. If unknown assume 8,500 Btu/hr¹⁴⁸

CEER_{base} = Efficiency of baseline unit

= As provided in tables above

CEER_{ee} = Efficiency of ENERGY STAR unit

= Actual; if unknown assume minimum qualifying standard as provided in tables above

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

$$\Delta kWh_{ENERGY STAR} = (330 * 8,500 * (1/11.1 - 1/14.7)) / 1,000$$

$$= 61.89 kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Btu/H * (\frac{1}{CEER_{base} * 1.01} - \frac{1}{CEER_{ee} * 1.01})}{1,000} * CF$$

¹⁴⁶ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹⁴⁷ The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling for the same 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.

¹⁴⁸ Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

$$\Delta kW = \text{Btu/H} * ((1/(\text{CEER}_{\text{base}} * 1.01) - 1/(\text{CEER}_{\text{ee}} * 1.01)))/1,000 * CF$$

Where:

CF = Summer Peak Coincidence Factor for measure

$$= 0.3^{149}$$

1.01 = Factor to convert CEER to EER (CEER includes standby and off power consumption).¹⁵⁰

Other variables as defined above.

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

$$\begin{aligned} \Delta kW_{\text{ENERGY STAR}} &= (8,500 * (1/(11.1 * 1.01) - 1/(14.7 * 1.01))) / 1,000 * 0.3 \\ &= 0.0557 \text{ kW} \end{aligned}$$

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-V04-250101

SUNSET DATE: 1/1/2027

¹⁴⁹ Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

¹⁵⁰ 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 3.5 years.¹⁵¹

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

$$\begin{aligned}\Delta kWh &= kWh_{exist} - (\%replaced * kWh_{newbase}) \\ &= \frac{Hours * BtuH}{EER_{exist} * 1,000} - (\%replaced * \frac{Hours * BtuH}{CEER_{NewBase} * 1,000})\end{aligned}$$

Where:

Hours = Full Load Hours of room air conditioning unit

Climate Zone (City Based Upon)	Hours ¹⁵²
Zone 5 (Burlington)	330

¹⁵¹ One-third of assumed measure life for Room AC, which was assumed to be 10.5 years, according to the Department of Energy, Office of Energy Efficiency and Renewable Energy; "Energy Conservation Program, Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners", 10 CFR Part 430 (Docket: EERE-2007-BT-STD-0010, pg. 22514).

¹⁵² The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008)) to FLH for Central Cooling for the same 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.

Climate Zone (City Based Upon)	Hours ¹⁵²
Zone 6 (Mason City)	168
Average/Unknown ¹⁵³	292

BtuH = Average size of rebated unit. Use actual if available – if not, assume 8,500¹⁵⁴

EERexist = Efficiency of recycled unit

= Actual if recorded – If not, assume 9.4¹⁵⁵

%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% ¹⁵⁶

CEERNewBase = Efficiency of new replacement baseline unit

= 10.5¹⁵⁷

Results using defaults provided above:

Climate Zone (City Based Upon)	ΔkWh		
	Unit Not Replaced	Unit Replaced	Unknown
Zone 5 (Burlington)	298.4	31.3	95.4
Zone 6 (Mason City)	151.9	15.9	48.6
Average/Unknown ¹⁵⁸	264.0	27.7	84.4

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure

¹⁵³ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹⁵⁴ Based on maximum capacity average from the RLW Report; “Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.”

¹⁵⁵ Federal efficiency standards for Room A/C manufactured between October 1, 2000 and May 31, 2014: 10 CFR 430.32(b) are at 9.8 EER- Weighted by capacity and equipment type based on available products on the EERE - Compliance Certification Database, that are non-ENERGY STAR units, as accessed 05/16/2022.

¹⁵⁶ 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.

¹⁵⁷ Federal efficiency standards for Room A/C manufactured after June 1, 2014: 10 CFR 430.32(b) are 10.9 CEER- Weighted by capacity and equipment type based on available products EERE - Compliance Certification Database, that are non-ENERGY STAR units, as accessed 05/16/2022.

¹⁵⁸ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

= 30%¹⁵⁹

Results using defaults provided above:

ΔkW		
Unit Not Replaced	Unit Replaced	Unknown
0.2713	0.0284	0.0867

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-V02-230101

SUNSET DATE: 1/1/2028

¹⁵⁹ Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

2.1.8 ENERGY STAR Air Purifier/Cleaner

DESCRIPTION

An air purifier (cleaner) meeting the efficiency specifications of ENERGY STAR¹⁶⁰ 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 30 Clean Air Delivery Rate (CADR) for PM_{2.5}¹⁶¹ to be considered under this specification.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb).
- Minimum Performance Requirements for PM_{2.5} as PM_{2.5} CADR per Watt as represented by Integrated Energy Factor (IEF) as listed below:¹⁶²

PM _{2.5} CADR Bins	Minimum IEF
30 ≤ CADR < 100	4.4
100 ≤ CADR < 150	5.4
CADR ≥ 150	5.6

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a conventional unit¹⁶³ that does not meet ENERGY STAR Efficiency Requirements.¹⁶⁴

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 9 years.¹⁶⁵

DEEMED MEASURE COST

The incremental cost for this measure is dependent on the Air Purifier size in CADR of PM_{2.5}.¹⁶⁶

Product Size	Average Purchase Cost (\$)	Average Incremental Cost (\$)	
		Non-IQ	IQ ¹⁶⁷
30 ≤ CADR < 100	\$117	\$0	\$19.50

¹⁶⁰ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

¹⁶¹ Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard.

¹⁶² ENERGY STAR Program Requirements for Room Air Cleaners - Eligibility Criteria V3.0.

¹⁶³ Meeting 10 CFR Part 430 Federal Energy Conservation Standards for Air Cleaners Tier 2, effective December 31, 2025.

¹⁶⁴ ENERGY STAR Program Requirements for Room Air Cleaners - Eligibility Criteria V3.0.

¹⁶⁵ ENERGY STAR Qualified Room Air Cleaner Calculator citing Appliance Magazine, Portrait of the U.S. Appliance Industry 1998.

¹⁶⁶ ENERGY STAR V3.0 Room Air Cleaners Data and Analysis. See file "ENERGY STAR V3.0 Room Air Cleaners Data and Analysis_VEIC".

¹⁶⁷ IQ Incremental costs factor in the assumption that a secondhand unit costs on average 50% of a new baseline unit, and that

Product Size	Average Purchase Cost (\$)	Average Incremental Cost (\$)	
		Non-IQ	IQ ¹⁶⁷
100 ≤ CADR < 150	\$193	\$76	\$82.83
CADR ≥ 150	\$398	\$55	\$103.00

LOADSHAPE

Loadshape E01 – Flat

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

$$kWh_{BASE} = (Hours * (\frac{CADR}{IEF_{BASE} * 1,000})) * IQAdj$$

$$kWh_{ESTAR} = (Hours * (\frac{CADR}{IEF_{ESTAR} * 1,000})) * IQAdj$$

Where:

1,000 = Conversion factor for W to kW

Hours = Annual active operating hours

= 5,840 hours¹⁶⁸

CADR = PM_{2.5} Clean Air Delivery Rate (CADR) for unit¹⁶⁹

= Actual; if Unknown:

Product Category	Clean Air Delivery Rate (cfm)
30 ≤ PM _{2.5} CADR < 100	58.4
100 ≤ PM _{2.5} CADR < 150	129.7
PM _{2.5} CADR ≥ 150	316.8

IEF_{BASE} = IEF for Baseline units¹⁷⁰.

= Actual; if Unknown:

Product Category	Efficiency _{BASE} (IEF)
10 ≤ PM _{2.5} CADR < 100	1.9
100 ≤ PM _{2.5} CADR < 150	2.4
PM _{2.5} CADR ≥ 150	2.9

1/3 of IQ participants would have purchased a unit on the secondhand market. See “IQ Appliance Calculations_IA.xls” for information.

¹⁶⁸ Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard.

¹⁶⁹ Based on data from ENERGY STAR Qualified Products List, accessed March 2026. Please see Analysis file.

¹⁷⁰ Meeting 10 CFR Part 430 Federal Energy Conservation Standards for Air Cleaners Tier 2, effective December 31, 2025.

IEF_{ESTAR} = IEF for ENERGY STAR units¹⁷¹.

= Actual; if Unknown:

Product Category	Efficiency _{ESTAR} (IEF)
30 ≤ PM _{2.5} CADR < 100	4.4
100 ≤ PM _{2.5} CADR < 150	5.4
PM _{2.5} CADR ≥ 150	5.6

IQAdj = Baseline consumption adjustment for IQ program participants to account for a portion of participants who would have utilized the secondary market.¹⁷²

= 1.0 if non-IQ, if IQ:

Product Category	IQAdj
30 ≤ PM _{2.5} CADR < 100	1.51
100 ≤ PM _{2.5} CADR < 150	1.46
PM _{2.5} CADR ≥ 150	1.22

Deemed energy savings using “Unknown” assumptions are as follows:

CADR Range	Energy Savings ΔkWh	
	Non-IQ	IQ
30 ≤ PM _{2.5} CADR < 100	102	194
100 ≤ PM _{2.5} CADR < 150	175	321
PM _{2.5} CADR ≥ 150	308	445

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

= Actual calculated, deemed values are as above:¹⁷³

Hours = Average hours of use per year

= 5,840 hours¹⁷⁴

CF = Summer Peak Coincidence Factor for measure

= 67%¹⁷⁵

¹⁷¹ ENERGY STAR v3.0 Minimum Qualifying IEF.

¹⁷² It is assumed that a second-hand unit is on average 2/3 of a measure’s EUL years old (6 years). The baseline consumption from the TRM in 2018 was increased by an estimate of 0.4% * 6 years (based on review of the refrigerator/freezer regression algorithm used in the 2.1.5 Refrigerator and Freezer Recycling measure) to account for degradation of performance over time. This second hand consumption was then weighted 1/3: 2/3 new baseline to estimate a multiplier for IQ participants. See “IQ Appliance Calculations_IA.xls” for information.

¹⁷³ Based on data from ENERGY STAR Qualified Products List, accessed March 2026. Please see Analysis file.

¹⁷⁴ Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator assumption of 16 hours per day (16 * 365 = 5840).

¹⁷⁵ Assumes that the purifier usage is evenly spread throughout the year, therefore coincident peak is calculated as 5844/8760 = 66.7%.

Deemed energy savings using “Unknown” assumptions are as follows:

	Clean Air Delivery Rate	ΔkW	
		Non-IQ	IQ
	$30 \leq CADR < 100$	0.012	0.022
	$100 \leq CADR < 150$	0.020	0.037
NATURAL GAS	$PM_{2.5} CADR \geq 150$	0.035	0.051

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

There are no operation and maintenance cost adjustments for this measure.¹⁷⁶

MEASURE CODE: RS-APL-AIRP-V06-270101

SUNSET DATE: 1/1/2030

¹⁷⁶ 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.

2.1.9 ENERGY STAR Dehumidifier

DESCRIPTION

A dehumidifier meeting the new minimum qualifying efficiency standard established by ENERGY STAR¹⁷⁷ Program (Version 6.0), effective October 1, 2025, and ENERGY STAR Most Efficient 2025 Criteria, effective, 01/01/2025, is purchased and installed in a residential setting in place of a baseline unit.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards as defined below¹⁷⁸:

Equipment Specification	Product Capacity (Pints/Day)	ENERGY STAR Criteria (L/kWh)	ENERGY STAR Most Efficient Criteria (L/kWh)
Portable Dehumidifier	≤ 25	≥ 1.70	≥ 1.85
	> 25 and ≤ 50	≥ 2.01	≥ 2.20
	> 50 and < 155	≥ 3.30	≥ 3.40

DEFINITION OF BASELINE EQUIPMENT

The baseline for this measure is defined as a new dehumidifier that meets the Code of Federal Regulations appliance federal efficiency standards¹⁷⁹. As of June 13, 2019, those are as defined below for Dehumidifiers:

Equipment Specification	Product Capacity (Pints/Day)	Federal Standard Criteria (L/kWh)
Portable Dehumidifier	≤ 25	≥ 1.30
	> 25 and ≤ 50	≥ 1.60
	> 50 and < 155	≥ 2.80

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years¹⁸⁰

¹⁷⁷ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

¹⁷⁸ ENERGY STAR Version 6.0 Program Requirements for Dehumidifiers, 10/01/2025

¹⁷⁹ Federal Standard 10 CFR 430.32

¹⁸⁰ EPA Research, 2012; ENERGY STAR Appliance Calculator, Dehumidifier Section, October 2016

DEEMED MEASURE COST

The incremental cost is the difference in cost between a baseline and an ENERGY STAR qualified unit. The incremental cost is assumed to be \$5¹⁸¹¹⁸², with no difference in incremental cost between ENERGY STAR and ENERGY STAR Most Efficient.

LOADSHAPE

Loadshape RE18 - Residential Dehumidifier

Coincidence Factor

The coincidence factor is assumed to be 50%¹⁸³

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = (((\text{Avg Capacity} * 0.473 / 24) * \text{Hours}) * (\text{IQAdj} / (\text{L} / \text{kWh}_{\text{Base}}) - 1 / (\text{L}/\text{kWh}_{\text{Eff}}))$$

Where:

Avg Capacity	= Capacity of dehumidifier in pints/day
	= Actual; if unknown assume capacity in each capacity range as provided in table below, or if capacity range unknown assume average
0.473	= Constant to convert Pints to Liters
24	= Constant to convert Liters/day to Liters/hour
Hours	= Run hours per year
	= Use actual data if known. If unknown use 2,200 hours ¹⁸⁴
IQAdj	= Baseline consumption adjustment for IQ program participants to account for a portion of participants who would have utilized the secondary market. ¹⁸⁵

¹⁸¹ EPA Research, 2016; ENERGY STAR Appliance Calculator, Dehumidifier Section, October 2016

¹⁸² IQ Incremental costs factor in the assumption that a secondhand unit costs on average 50% of a new baseline unit, and that 1/3 of IQ participants would have purchased a unit on the secondhand market. The new baseline dehumidifier is assumed to cost \$150. See "IQ Appliance Calculations_IA.xls" for information.

¹⁸³ Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). With 2,200 operating hours, coincidence peak during summer peak is therefore 2200/4392 = 50.1%.

¹⁸⁴ Based on Mattison et al., "Dehumidifiers: A Major Consumer of Residential Electricity", Cautley et al., "Dehumidification and Subslab Ventilation in Wisconsin Homes" and Yang et al., "Dehumidifier Use in the U.S. Residential Sector", all indicating average usage around 2,200 hours per year.

¹⁸⁵ It is assumed that a second-hand unit is on average 1/3 of a measure's EUL years old (8 years). In 2019 a new Federal Standard became effective and "relative to the previous standard, the current standard represents energy savings of about 15-25%". 20% was used, and increased by an estimate of 0.4% * 8 years (based on review of the refrigerator/freezer regression

= 1.096 if IQ, 1.0 if non-IQ

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

L/kWh_Eff = Efficient unit liters of water per kWh consumed, as provided in ENERGY STAR table above

Deemed Annual kWh usage and savings if ‘unknown’, for each capacity class and product type, are presented in the tables below:

Portable Dehumidifiers					Annual kWh			
Capacity	Capacity Used	Federal Standard Criteria	ENERGY STAR Criteria	ENERGY STAR Most Efficient Criteria	Non-IQ Baseline Federal Standard	IQ Baseline	ENERGY STAR Criteria	ENERGY STAR Most Efficient Criteria
(pints/day)	(pints/day)	(≥ L/kWh)	(≥ L/kWh)	(≥ L/kWh)				
≤25	22.0	1.30	1.70	1.85	734	805	561	516
>25 and ≤50	43.4	1.60	2.01	2.20	1175	1287	935	854
>50 and <155	83.2	2.80	3.30	3.40	1288	1411	1092	1060
Average	49.5	1.90	2.24	2.48	1130	1238	919	864

Portable Dehumidifiers		Energy Savings (ΔkWh)			
Capacity	Capacity Used	Non-IQ		IQ	
		ENERGY STAR Criteria	ENERGY STAR Most Efficient Criteria	ENERGY STAR Criteria	ENERGY STAR Most Efficient Criteria
(pints/day)	(pints/day)				
≤25	22.0	173	218	243	289
>25 and ≤50	43.4	240	320	352	433
>50 and <155	83.2	195	227	319	351
Average	49.5	211	265	320	374

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

CF = Summer Peak Coincidence Factor for measure

algorithm used in the 2.1.5 Refrigerator and Freezer Recycling measure) to account for degradation of performance over time. This second hand consumption was then weighted 1/3: 2/3 current new baseline to estimate a multiplier for IQ participants. See “IQ Appliance Calculations.xls” for information.

$$= 50\%^{186}$$

Deemed Annual kW usage and savings if “Unknown,” for each capacity class and product type, are presented in the tables below:

Portable Dehumidifier	Energy Savings (Δ kW)			
	Non-IQ		IQ	
Capacity Range	ENERGY STAR	ENERGY STAR Most Efficient	ENERGY STAR	ENERGY STAR Most Efficient
(pints/day)				
≤ 25	0.039	0.050	0.055	0.066
>25 and ≤ 50	0.054	0.073	0.080	0.098
>50 and <155	0.044	0.052	0.072	0.080
Average	0.048	0.060	0.073	0.085

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-DEHUM-V03-260101

SUNSET DATE: 1/1/2029

¹⁸⁶ Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). With 2200 operating hours, coincidence peak during summer peak is therefore $2200/4392 = 50.1\%$

2.1.10 Residential Induction Cooktop

DESCRIPTION

An induction cooktop installed in place of an electric resistance cooktop.

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 cooktop that heats cooking vessels using electrical induction in residential applications.

DEFINITION OF BASELINE EQUIPMENT

The baseline reflects the cooking efficiencies of electric resistance cooktops. Cooking efficiency is defined as the ratio of energy absorbed by the object being heated (food, water, etc.) and the energy consumed by the appliance. The baseline cooking efficiency is assumed to be 77%.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the measure is 16 years.¹⁸⁸

DEEMED MEASURE COST

The incremental cost of induction cooktop only over resistance cooktop is \$687¹⁸⁹. In addition, assume \$100 additional labor to install additional power/socket requirements.

LOADSHAPE

Loadshape RE20 – Residential Induction Cooktop

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY AND FOSSIL FUEL SAVINGS

$$\Delta \text{kWh} = \text{CooktopAEC}_{\text{base}} - \text{CooktopIAEC}_{\text{ee}}$$

Where:

$$\text{CooktopIAEC}_{\text{ee}} = \text{Integrated Annual Energy Consumption of an induction cooktop}^{190} \text{ in kWh/yr}$$

¹⁸⁷ The cooking efficiencies of electric resistance and induction cooktops are tested and calculated in the *Residential Cooktop Performance and Energy Comparison Study* conducted by Frontier Energy, July 2019.

¹⁸⁸ The EUL was developed for the U.S. Department of Energy (DOE) Energy Conservation Program, Energy Conservation Standards for Residential Conventional Cooking Products as part of the 2016 supplemental notice of proposed rulemaking (SNOPR).

¹⁸⁹ Southern California Edison (SCE). 2019. "SWAP015-01 Costs.xlsx".

¹⁹⁰ The energy measurements are performed at an ISO/IEC 17025 accredited lab as specified in the application process for the

= Actual; if IAEC is unknown, assume 111 kWh/yr¹⁹¹

CooktopAEC_{base} = Annual Energy Consumption of a baseline electric cooktop in kWh/yr

= CooktopIAEC_{ee} * (Eff_{ee} / Eff_{base})

= If values unknown, assume 111 * 0.85/0.77 = 122.5 kWh/yr

Eff_{ee} = cooking efficiency of the induction cooktop

= Actual. If unknown, assume 85%¹⁹²

Eff_{base} = cooking efficiency of baseline cooktop

= Actual; if unknown, assume 77%¹⁹³ for electric resistance cooktop

A residential induction cooktop will replace an electric resistance cooktop. The annual energy consumption of the induction cooktop has not been measured. The electric savings are calculated below:

$$\begin{aligned}\Delta\text{kWh} &= \text{CooktopAEC}_{\text{base}} - \text{CooktopIAEC}_{\text{ee}} \\ \text{CooktopIAEC}_{\text{ee}} &= 111 \text{ kWh/yr} \\ \text{CooktopAEC}_{\text{base}} &= 111 * (0.85 / 0.77) \\ &= 122.5 \text{ kWh/yr} \\ \Delta\text{kWh} &= 122.5 - 111 \\ &= 11.5 \text{ kWh/yr}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = (\text{CooktopAEC}_{\text{base}} - \text{CooktopIAEC}_{\text{ee}}) / \text{Hours} * \text{CF}$$

Where:

Hours = Annual operating hours¹⁹⁴
= 239 hours

ENERGY STAR Emerging Technology Award. Approved products on the ENERGY STAR Qualified Products List have IAEC values listed.

¹⁹¹ Average Integrated Annual Energy Consumption (IAEC) of an induction cooktop on the ENERGY STAR Emerging Technology Award Qualified Products List, accessed June 2022, is 111 kWh.

¹⁹² The cooking efficiencies of electric resistance, gas, and induction cooktops are tested and calculated in the *Residential Cooktop Performance and Energy Comparison Study* conducted by Frontier Energy.

¹⁹³ Ibid.

¹⁹⁴ Assuming 1 hours per cycle and 239 cycles per year therefore 239 operating hours per year. 239 cycles per year is based on a 2016 CASE study for PG&E modeling Plug Loads.

CF = Summer Peak Coincidence Factor

= 24%¹⁹⁵

All other variables as presented above.

A residential induction cooktop will replace an electric resistance cooktop. The annual energy consumption of the induction cooktop has not been measured. The electric savings are calculated below:

$$\begin{aligned}\Delta kW &= (122.5 - 111) / 239 * 0.24 \\ &= 0.0115\end{aligned}$$

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-INDC-V01-250101

SUNSET DATE: 1/1/2028

¹⁹⁵ Calculated for IA summer peak period from ResStock, 15 minute interval data by end use, as provided by NREL.

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 8 years.¹⁹⁶

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 \$9¹⁹⁷ (\$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%.¹⁹⁸

¹⁹⁶ This is a consistent assumption with 2.2.2 Advanced Power Strip – Tier 2.

¹⁹⁷ 2016 Price survey performed by Illume Advising LLC, see “Current Surge Protector Costs and Comparison 7-2016” spreadsheet.

¹⁹⁸ 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 kWh¹⁹⁹

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

Installation	$Weighting_{Office}$
Home Office	100%
Home Entertainment System	0%
Unknown	41% ²⁰⁰

kWh_{Ent} = Estimated energy savings from using an APS in a home entertainment system
= 75.1 kWh²⁰¹

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

Installation	$Weighting_{Ent}$
Home Office	0%
Home Entertainment System	100%
Unknown	59% ²⁰²

ISR = In service rate
= 87%²⁰³

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

$$\begin{aligned}\Delta kWh_{office} &= (31 * 100\% + 75.1 * 0\%) * 0.87 \\ &= 27.0 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\Delta kWh_{Ent} &= (31 * 0\% + 75.1 * 100\%) * 0.87 \\ &= 65.3 \text{ kWh}\end{aligned}$$

¹⁹⁹ 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.

²⁰⁰ 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.

²⁰¹ NYSERDA 2011, Advanced Power Strip Research Report.

²⁰² 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.

²⁰³ Based on MidAmerican Energy Company & TetraTech "Residential Assessment Impact and Process Evaluation FINAL". December 22, 2020, APPENDIX B: IN-SERVICE RATES ANALYSIS, p. 47.

$$\begin{aligned}\Delta \text{kWh}_{\text{unknown}} &= (31 * 41\% + 75.1 * 59\%) * 0.87 \\ &= 49.6 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} * \text{CF}$$

Where:

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

$$= 7,129^{204}$$

CF = Summer Peak Coincidence Factor for measure

$$= 80\%^{205}$$

$$\begin{aligned}\Delta \text{kW}_{\text{office}} &= 27.0 / 7129 * 0.8 \\ &= 0.0030 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta \text{kW}_{\text{Ent}} &= 65.3 / 7129 * 0.8 \\ &= 0.0073 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta \text{kW}_{\text{unknown}} &= 49.6 / 7129 * 0.8 \\ &= 0.0056 \text{ kW}\end{aligned}$$

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-V05-270101

SUNSET DATE: 1/1/2030

²⁰⁴ Average of hours for controlled TV and computer from; NYSERDA Measure Characterization for Advanced Power Strips.

²⁰⁵ 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;²⁰⁶ 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.²⁰⁷

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The default deemed lifetime value for Tier 2 AV APS is assumed to be 8 years.²⁰⁸

²⁰⁶ 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.

²⁰⁷ 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.

²⁰⁸ Measure life from Slipstream Inc, “Field Study of Tier 2 Advanced Power Strips”, 01/31/2019, p.51.

Iowa Energy Efficiency Statewide Technical Reference Manual—2.2.2 Tier 2 Advanced Power Strips (APS) – Residential Audio Visual

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 \$70.²⁰⁹

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%.²¹⁰

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = \text{ERP} * \text{BaselineEnergy}_{\text{AV}} * \text{ISR}$$

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} = 443 kWh²¹¹

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:

Control Strategy	ΔkWh
Infrared Only	126.4
Infrared and Occupancy Sensor	89.8

²⁰⁹ Based on internet review of leading manufacturers, 3/2026.

²¹⁰ In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.

²¹¹ 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”, March 18, 2019, p. 54. Note that this load represents the average *controlled* AV devices only and will likely be lower than total AC usage.

Iowa Energy Efficiency Statewide Technical Reference Manual—2.2.2 Tier 2 Advanced Power Strips (APS) – Residential Audio Visual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

ΔkWh = Energy savings as calculated above

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

$$= 4,380^{212}$$

CF = Summer Peak Coincidence Factor for measure

$$= 80\%^{213}$$

Based upon default assumptions above, savings are as follows:

Control Strategy	ΔkW
Infrared Only	0.0231
Infrared and Occupancy Sensor	0.0164

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-V06-270101

SUNSET DATE: 1/1/2030

²¹² 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.

²¹³ 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 (or instantaneous) 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.²¹⁴

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 STAR²¹⁵ criteria.

Unit Type	Unit Capacity	ENERGY STAR v5.0 Requirements (Uniform Energy Factor)
Gas Storage	≤ 55 gallons	Medium Draw Pattern UEF ≥ 0.81 High Draw Pattern UEF ≥ 0.86
	> 55 gallons	UEF ≥ 0.86
Gas Tankless	All	UEF ≥ 0.95

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 $0.6483 - (0.0017 * \text{storage capacity in gallons})$ and $0.7897 - (0.0004 * \text{storage capacity in gallons})$ for greater than 55 gallon storage water heaters.²¹⁶

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

²¹⁴ 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.

²¹⁵ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

²¹⁶ Minimum Federal standard as of 4/16/2015; Code of Federal Regulations Title 10 Chapter II Subchapter D Part 430 Subpart C 430.32.

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.²¹⁷

For Early Replacement: The remaining life of existing equipment is assumed to be 3.7 for gas storage water heaters and 6.7 years for gas tankless water heaters.²¹⁸

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.²¹⁹

Water Heater Type	Water Heater Tank Volume (gallons)	Draw Pattern	Baseline Cost	Incremental Capital Cost	Full Install Cost
Efficient Storage	≤ 55	Medium	\$1,738	\$230	\$1,968
		High	\$1,836	\$215	\$2,051
	> 55	All	\$1,836	\$215	\$2,051
Efficient Tankless	All	All	\$1,661	\$293	\$1,954

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 provided in the table above. This cost should be discounted to present value using the utility's discount rate.²²⁰

LOADSHAPE

Loadshape RG07 – Residential Water Heat (gas)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

²¹⁷ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014.

²¹⁸ Assumes one third of the expected equipment life.

²¹⁹ Supporting document for Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. 2023-07-21 Consumer Water Heater Life-Cycle Cost (LCC) and Payback Period Results Analysis (NOPR), EERE-2017-BT-STD-0019-0061.

²²⁰ Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = (1/UEF_{Base} - 1/UEF_{EE}) * (GPD * Household * 365 * \gamma Water * (T_{Out} - T_{In}) * 1.0) / 100,000$$

Early Replacement:²²¹

$\Delta Therms$ for remaining life of existing unit (1st 3.7 years for gas storage unit and 1st 6.7 years for gas tankless unit):

$$\Delta Therms = (1/UEF_{Existing} - 1/UEF_{EE}) * (GPD * Household * 365 * \gamma Water * (T_{Out} - T_{In}) * 1.0) / 100,000$$

$\Delta Therms$ for remaining measure life (next 7.3 years for gas storage unit and next 13.3 years for gas tankless unit):

$$\Delta Therms = (1/UEF_{Base} - 1/UEF_{EE}) * (GPD * Household * 365 * \gamma Water * (T_{Out} - T_{In}) * 1.0) / 100,000$$

Where:

UEF_{Base} = UEF (efficiency) rating of standard storage water heater according to federal standards²²²

= 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; if unknown, assume:²²³

Unit Type	Unit Capacity	Uniform Energy Factor
Gas Storage	≤ 55 gallons	0.81
	> 55 gallons	0.86
Gas Tankless	All	0.95

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

²²¹ 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).

²²² Minimum Federal standard since 1/1/2015

²²³ ENERGY STAR Product Specification for Residential Water Heaters, Version 5.0, effective April 18, 2023. For Gas Storage Unit Types, Medium Draw Pattern was used for the minimum UEF.

= Actual; if unknown, assume 0.52²²⁴

GPD = Gallons per day of hot water use per person

= 17.6²²⁵

Household = Average number of people per household

Household Unit Type	Household
Manufactured	1.96 ²²⁶
Single-Family – Deemed	2.55 ²²⁷
Multifamily – Deemed	1.71 ²²⁸
Custom	Actual Occupancy or Number of Bedrooms ²²⁹

365 = Number of days per year

γ_{Water} = Specific weight of water

= 8.33 pounds per gallon

T_{Out} = Tank temperature

= 126.5°F ²³⁰

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

= 57.8°F²³¹

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:

$$\Delta \text{Therms} = (1/0.5633 - 1/0.81) * (17.6 * 2.55 * 365 * 8.33 * (126.5 - 57.8) * 1.0) / 100,000$$

$$= 50.7 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} / 365$$

²²⁴ Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.

²²⁵ Deoreo, B., and P. Mayer. Residential End Uses of Water Study 2013 Update. Water Research Foundation, 2014.

²²⁶ Average household size by building type and water heater fuel type based on the 2007 RASS.

²²⁷ NREL ResStock building characteristic data released in 2022.

²²⁸ Ibid.

²²⁹ 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.

²³⁰ CPUC Residential Retrofit - High Impact Measure Evaluation Report Draft. Dec. 7, 2009. Pg 76. Average temperature setpoints for two utilities.

²³¹ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. For more details, see 'Hot Water – Temps to DHW Tank Calc.xlsx.'

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:

$$\begin{aligned}\Delta\text{PeakTherms} &= 50.7/365 \\ &= 0.1389 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-GWHT-V06-240101

SUNSET DATE: 1/1/2030

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.²³²

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 STAR²³³ Heat Pump domestic water heater.²³⁴ On April 18, 2023, a new version of the ENERGY STAR Water Heater Program Requirements became effective (Version 5.0), with the following efficiency requirements:

Unit Type	ENERGY STAR Requirements (Uniform Energy Factor)
Integrated HPWH	UEF $\geq$ 3.3
Integrated HPWH, 120 Volt / 15 Amp Circuit	UEF $\geq$ 2.2
Split-system HPWH	UEF $\geq$ 2.2

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a new electric water heater meeting federal minimum efficiency standards,²³⁵ dependent on the storage volume (in gallons) of the water heater.

For units $\leq$ 55 gallons – resistance storage unit with efficiency: $0.9307 - (0.0002 * \text{rated volume in gallons})$

For units $>$ 55 gallons – assume a 50 gallon resistance tank baseline²³⁶ i.e. 0.9207 UEF.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.²³⁷

DEEMED MEASURE COST

For Time of Sale or New Construction the incremental installation cost (including labor) should be used. Defaults are provided below. 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).

²³² 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.

²³³ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

²³⁴ If the water heater does not have a UEF rating, but a EF rating, revert to using the previous version of this measure.

²³⁵ Minimum Federal Standard as of 4/1/2015. Medium draw pattern; Code of Federal Regulations Title 10 Chapter II Subchapter D Part 430 Subpart C 430.32.

²³⁶ A 50 gallon volume tank for the baseline is assumed to capture market practice of using larger heat pump water heaters to achieve greater efficiency of the heat pump cycle and preventing the unit from going in electric resistance mode.

²³⁷ ComEd Effective Useful Life Research Report, prepared by Navigant, May 14, 2018, page 24.

Capacity	Baseline Installed Cost ²³⁸	Efficient Installed Cost ²³⁹	Incremental Installed Cost
≤55 gallons	\$882	\$2,293	\$1,411
>55 gallons	\$882	\$3,086	\$2,204

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**

$$\Delta kWh = \left(\frac{(1/UEF_{BASE} - 1/UEF_{EE}) * GPD * Household * 365 * \gamma_{Water} * (T_{OUT} - T_{in}) * 1.0}{3412} \right) + kWh_{cool} - kWh_{heat}$$

Where:

UEF_{BASE} = Uniform Energy Factor (efficiency) of standard electric water heater according to federal standards:²⁴⁰

For ≤55 gallons: 0.9307 – (0.0002 * rated volume in gallons), Actual volume should be used, if unknown:

= 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 household²⁴¹

= 17.6

Household = Average number of people per household

Household Unit Type	Household
Manufactured	1.96 ²⁴²

²³⁸ Average total installed cost of an electric resistance storage water heater sourced from Heat Pump Water Heaters in the Northeast and Mid-Atlantic: Costs and Market Trends prepared by Energy Solutions, June 17, 2024, page 34.

²³⁹ Efficient Equipment costs are based on measure cost information from SWWH025_Costing_Analysis_2025-11-07 supporting document, with a focus on 240V HPWH costs.

²⁴⁰ Minimum Federal Standard as of 1/1/2015. CFR, Title 10: Energy, Chapter II D §430.32(d) Energy and water conservation standards and their compliance dates. (Water Heaters).

²⁴¹ Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

²⁴² Average household size by building type and water heater fuel type based on the 2007 RASS.

Household Unit Type	Household
Single-Family – Deemed	2.55 ²⁴³
Multifamily – Deemed	1.71 ²⁴⁴
Custom	Actual Occupancy or Number of Bedrooms ²⁴⁵

365 = Days per year

γ_{Water} = Specific weight of water
= 8.33 pounds per gallon

T_{OUT} = Tank temperature
= 126.5°F ²⁴⁶

T_{IN} = Incoming water temperature from well or municipal system
= 57.8²⁴⁷

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 heat²⁴⁸

$$= \left[\frac{\left(\left(1 - \frac{1}{UEF_{EE}} \right) * GPD * Household * 365 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 34\% * LM}{COP_{COOL} * 3412} \right] * \%Cool$$

Where:

LF = Location Factor²⁴⁹
= 1.0 for HPWH installation in a conditioned space
= 0.94 for HPWH installation in an unknown location²⁵⁰
= 0.0 for installation in an unconditioned space

²⁴³ NREL ResStock building characteristic data released in 2022.

²⁴⁴ Ibid

²⁴⁵ 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.

²⁴⁶ CPUC Residential Retrofit - High Impact Measure Evaluation Report Draft. Dec. 7, 2009. Pg 76. Average temperature setpoints for two utilities.

²⁴⁷ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. See 'Hot Water – Temps to DHW Tank Calc.xlsx' for more details.

²⁴⁸ 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.

²⁴⁹ 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 does not in itself imply the space is conditioned.

²⁵⁰ Weighted average determined by program data of Installation location conditioned vs unconditioned, provided by Alliant Energy 4/12/2023 for installations dates from 2022 to present.

34%	= Portion of reduced waste heat that results in cooling savings ²⁵¹
COP _{COOL}	= COP of Central Air Conditioner
	= Actual; if using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time, ²⁵² . If unknown, assume 2.79 ²⁵³
LM	= Latent multiplier to account for latent cooling demand
	= 1.33 ²⁵⁴
%Cool	= Percentage of homes with central cooling

Cooling System	%Cool
Central Air Conditioner	100%
No Central Air Conditioner	0%
Unknown ²⁵⁵	91%

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

$$= \left(\frac{\left(\left(1 - \frac{1}{UEF_{EE}} \right) * GPD * Household * 365 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 53\%}{COP_{HEAT} * 3412} \right) * \%ElectricHeat$$

Where:

53%	= Portion of reduced waste heat that results in increased heating load ²⁵⁶
COP _{HEAT}	= COP of electric heating system
	= Actual system efficiency including duct loss. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time, ²⁵⁷ - If not available, use: ²⁵⁸

²⁵¹ 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).

²⁵² Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

²⁵³ The federal standard between 2015-2022 is used to estimate the average existing efficiencies; 14 SEER (13.3 SEER2) for Central ASHP and 11.56 SEER (10.982 SEER2) for Baseline Central AC Equipment, weighted based on ResStock data for the state of Iowa. An 85% distribution efficiency is then applied to account for duct losses.

²⁵⁴ 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.

²⁵⁵ Based on assumption that 91% of homes have central cooling (based on ResStock data for the state of Iowa).

²⁵⁶ 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).

²⁵⁷ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

²⁵⁸ 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	HSPF2 Estimate	η_{Heat} (Effective COP Estimate) (HSPF2/3.412)*0.85
Heat Pump	Before 2006	5.78 (6.8 HSPF)	1.44
	2006 - 2014	6.54 (7.7 HSPF)	1.63
	2015 on	7.5 (8.2 HSPF)	1.9
Resistance	N/A	N/A	1
Unknown	N/A	N/A	1.2 ²⁵⁹

%ElectricHeat = Factor dependent on heating fuel:

Heating System	%ElectricHeat
Electric resistance or heat pump	100%
Gas	0%
Unknown heating fuel ²⁶⁰	24%

For example, for a 2.2 UEF 50 gallon heat pump water heater in a single family home, in a conditioned location, using default assumptions provided above:

$$\begin{aligned} \text{kWh}_{\text{cool}} &= (((1 - 1/2.2) * 17.6 * 2.55 * 365 \text{mm} * 8.33 * (126.5 - 57.8) * 1.0 * 1.0 * 0.34 * 1.33) \\ &\quad / (2.79 * 3,412)) * 0.91 \\ &= 221 \text{ kWh} \end{aligned}$$

$$\begin{aligned} \text{kWh}_{\text{heat}} &= (((1 - 1/2.2) * 17.6 * 2.55 * 365 * 8.33 * (126.5 - 57.8) * 1.0 * 1.0 * 0.53) / (1.2 * \\ &\quad 3,412)) * 0.24 \\ &= 158.9 \text{ kWh} \end{aligned}$$

$$\begin{aligned} \Delta \text{kWh} &= ((1 / 0.9207 - 1 / 2.2) * 17.6 * 2.55 * 365 * 8.33 * (126.5 - 57.8)) / 3,412 + 183.5 - 221 \\ &= 1,697.8 \text{ kWh} \end{aligned}$$

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

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

Where:

Hours = Full load hours of water heater
= 5,186²⁶¹

CF = Summer Peak Coincidence Factor for measure

²⁵⁹ Using the current federal standard of 7.5 HSPF2 for Central ASHP and averaged with electric resistance COPheat, weighted based on ResStock data for the state of Iowa.

²⁶⁰ Based on ResStock data for the state of Iowa.

²⁶¹ Full load hours assumption based on analysis of loadshape data provided by Cadmus.

$$= 33\%^{262}$$

For example, for a 2.2 UEF 50 gallon heat pump water heater using default assumptions provided above:

$$\begin{aligned}\Delta kW &= 1,697.8 / 5,186 * 0.33 \\ &= 0.1080 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta Therms = - \left(\frac{\left(\left(1 - \frac{1}{UEF_{EE}} \right) * GPD * Household * 365 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0 \right) * LF * 53\%}{\eta_{Heat} * 100,000} \right) * \%GasHeat$$

Where:

$\Delta Therms$ = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat²⁶³

0.03412 = conversion factor (therms per kWh)

η_{Heat} = Efficiency of heating system, i.e., AFUE multiplied by distribution efficiency²⁶⁴
= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time²⁶⁵ - If not available, use 74%.²⁶⁶

$\%GasHeat$ = Factor dependent on heating fuel:

Heating System	$\%GasHeat$
Electric resistance or heat pump	0%
Natural Gas	100%
Unknown heating fuel ²⁶⁷	75%

²⁶² 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 as (average kW usage during peak period) / [(annual kWh savings / FLH)] = (0.1 kW) / [(1,556 kWh (default assumptions) / 5,183 hours) = 0.33.

²⁶³ 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.

²⁶⁴ 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, "Guidance on Estimating Distribution Efficiency" or by performing duct blaster testing.

²⁶⁵ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

²⁶⁶ This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant space heating system is a central warm-air furnace, and energy source of natural gas (based on Energy Information Administration, 2019 Residential Energy Consumption Survey, HC6.9 for the Midwest)). 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.

²⁶⁷ Based on NREL ResStock data for the state of Iowa.

Other factors as defined above.

For example, for a 2.2 UEF 50 gallon heat pump water heater using default assumptions provided above:

$$\begin{aligned}\Delta\text{Therms} &= -(((1 - 1/2.2) * 17.6 * 2.55 * 365 * 8.33 * (126.5 - 57.8) * 1.0 * 1.0 * 0.53) / (0.74 * \\ &100,000)) * 0.75 \\ &= - 27.5 \text{ therms}\end{aligned}$$

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:

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

Where:

$$\begin{aligned}\Delta\text{Therms} &= \text{Therm impact calculated above} \\ \text{HeatDays} &= \text{Heat season days per year} \\ &= 215^{268}\end{aligned}$$

For example, for a 2.2 UEF 50 gallon heat pump water heater, using default assumptions provided above:

$$\begin{aligned}\Delta\text{PeakTherms} &= -27.5 / 215 \\ &= - 0.1279 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-HPWH-V07-270101

SUNSET DATE: 1/1/2030

²⁶⁸ Calculated number of days where HDD 60 >0. NCDC U.S. Climate Hourly Normals 15-year data set (2006-2020) for Des Moines. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

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.²⁶⁹

DEEMED MEASURE COST

The incremental cost of a setback is assumed to be \$10 for contractor time.²⁷⁰

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 SAVINGS²⁷¹**

For homes with electric DHW tanks:

²⁶⁹ Professional judgment.

²⁷⁰ Based on labor cost of \$40/hr and 15 min work.

²⁷¹ 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.

$$\Delta kWh = \frac{(U * A * (T_{pre} - T_{post}) * Hours)}{3,412 * RE_{electric}}$$

Where:

- U = Overall heat transfer coefficient of tank (Btu/Hr-°F-ft²)
 = 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 = 24.99ft².²⁷²

Capacity (gal)	A (ft ²) ²⁷³
30	19.16
40	23.18
50	24.99
80	31.84

- T_{pre} = Actual hot water setpoint prior to adjustment. If unknown, assume 135°F
- T_{post} = Actual new hot water setpoint, which may not be lower than 120°F. If unknown, assume 120°F.
- Hours = Number of hours in a year (since savings are assumed to be constant over year)
 = 8,760
- 3412 = Conversion from Btu to kWh
- RE_{electric} = Recovery efficiency of electric hot water heater
 = 98%²⁷⁴
 = 200%²⁷⁵ for heat pump water heaters

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

$$\Delta kWh = (0.083 * 24.99 * (135 - 120) * 8,760) / (3,412 * 0.98)$$

$$= 81.5 \text{ kWh}$$

²⁷² Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual; Table 2 57: Terms, Values, and References for Water Heater Temperature Setback. 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.

²⁷³ Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual.

Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

²⁷⁴ Electric water heaters have recovery efficiency of 98% based on a review of the AHRI Directory.

²⁷⁵ 200% 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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

Hours = 8,760

CF = Summer Peak Coincidence Factor for measure
= 100%

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

$$\begin{aligned}\Delta kW &= (81.6 / 8,760) * 1 \\ &= 0.0093 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

For homes with gas water heaters:

$$\Delta Therms = \frac{U * A * (T_{pre} - T_{post}) * Hours}{100,000 * RE_{gas}}$$

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 homes²⁷⁶

= 78% for MF homes with storage tank or dedicated gas DHW system,

= 59% for MF homes with hot water through central boiler,

= 69% for MF homes with unknown water heater type²⁷⁷

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:

$$\begin{aligned}\Delta Therms &= (0.083 * 24.99 * (135 - 120) * 8,760) / (100,000 * 0.78) \\ &= 3.5 \text{ Therms}\end{aligned}$$

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 47.80ft²:

$$\Delta Therms = (0.083 * 47.80 * (135 - 120) * 8,760) / (100,000 * 0.60)$$

²⁷⁶ 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%.

²⁷⁷ 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.

= 8.7 Therms

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therms 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:

$$\begin{aligned} \Delta PeakTherms &= 3.5 * 0.002952 \\ &= 0.0103 \text{ Therms} \end{aligned}$$

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 47.80ft²:

$$\begin{aligned} \Delta PeakTherms &= 8.7 * 0.002952 \\ &= 0.0257 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-TMPS-V04-270101

SUNSET DATE: 1/1/2031

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)²⁷⁸ 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 GPM²⁷⁹ or greater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.²⁸⁰

DEEMED MEASURE COST

For RF and DI, the incremental cost for this measure is \$16 or program actual.²⁸¹

For TOS and NC, the incremental cost is \$0.²⁸²

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)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted (unless faucet type is unknown, then it is per household).²⁸³

²⁷⁸ IPL program product data for 2014 Iowa Residential Energy Assessments.

²⁷⁹ DOE Energy Cost Calculator for Faucets and Showerheads.

²⁸⁰ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation," California Public Utilities Commission, January, 2014."

²⁸¹ 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).

²⁸² 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.

²⁸³ This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.

$$\Delta kWh = \%ElectricDHW * ((GPM_base - GPM_low) * L * Household * 365 * \frac{DF}{FPH}) * EPG_electric * ISR$$

Where:

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

DHW Fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	36% ²⁸⁴

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

= Measured full throttle flow * 0.83 throttling factor²⁸⁵

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 factor²⁸⁶

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	4.5 ²⁸⁷
Bathroom	1.6 ²⁸⁸
If location unknown (total for household): Single-Family	9.0 ²⁸⁹
If location unknown (total for household): Multifamily	6.9 ²⁹⁰

Household = Average number of people per household

Household Unit Type	Household
Single-Family – Deemed	2.55 ²⁹¹

²⁸⁴ Default assumption for unknown fuel is based on ResStock data for the state of Iowa. 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.

²⁸⁵ 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.

²⁸⁶ 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.

²⁸⁷ 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.

²⁸⁸ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

²⁸⁹ One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd, Illinois residential survey of 140 sites, provided by Cadmus.

²⁹⁰ One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd, Illinois residential survey of 140 sites, provided by Cadmus.

²⁹¹ NREL ResStock building characteristic data released in 2022.

Household Unit Type	Household
Multifamily – Deemed	1.71 ²⁹²
Custom	Actual Occupancy or Number of Bedrooms ²⁹³

365 = Days in a year, on average

DF = Drain Factor

Faucet Type	Drain Factor ²⁹⁴
Kitchen	75%
Bath	90%
Unknown	79.5%

FPH = Faucets Per Household

Faucet Type	FPH
Kitchen or Bathroom (i.e., divide by 1 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

$$= (\gamma_{\text{Water}} * 1.0 * (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{electric}} * 3,412)$$

 = 0.0703 kWh/gal (Bath), 0.0877 kWh/gal (Kitchen), 0.0827 kWh/gal (Unknown) if resistance tank (or unknown)
 = 0.0344 kWh/gal (Bath), 0.0430 kWh/gal (Kitchen), 0.0405 kWh/gal (Unknown) if heat pump water heater

Where:

γ_{Water} = 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

= 86°F for Bath, 93°F for Kitchen 91°F for Unknown²⁹⁵

²⁹² NREL ResStock building characteristic data released in 2022.

²⁹³ 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.

²⁹⁴ 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 $(0.7 * 0.75) + (0.3 * 0.9) = 0.795$.

²⁹⁵ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to

SupplyTemp = Assumed temperature of water entering house
= 57.8²⁹⁶

RE_electric = Average Recovery efficiency of electric water heater
= 98%²⁹⁷ for electric resistance (or unknown)
= 200%²⁹⁸ for heat pump water heaters

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

ISR = In service rate of faucet aerators

Program		ISR
Direct-install, NC, or TOS		0.95 ²⁹⁹
Efficiency Kits – Residential	Kitchen	0.74 ³⁰⁰
	Bathroom	0.46 ³⁰¹
	Unknown	0.60 ³⁰²
Efficiency Kits –Schools ³⁰³		0.43

Based on defaults provided above:

Program	Faucet	Market/Program	Algorithm	ΔkWh
Direct-install, NC, or TOS	Kitchen	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0877 * 0.95$	104.7
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0430 * 0.95$	51.3
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0877 * 0.95$	37.7
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0877 * 0.95$	70.2
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0430 * 0.95$	34.4

Michigan Evaluation Working Group. If the aerator location is unknown, an average of 91°F should be used, which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom:
 $(0.7 * 93) + (0.3 * 86) = 0.91$.

²⁹⁶ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20. Water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. See 'Hot Water – Temps to DHW Tank Calc.xls' in 2.3.1 Gas Water Heater analysis files for more details.

²⁹⁷ Electric water heaters have recovery efficiency of 98% from AHRI Directory

²⁹⁸ 200% 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.

²⁹⁹ 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.

³⁰⁰ Based on Cadmus, "Final Report: Iowa 2015 Energy Wise Program", January 29, 2016, p. 16.

³⁰¹ Weighted average MidAmerican Energy Company & TetraTech "Residential Assessment Impact and Process Evaluation FINAL". December 22, 2020, APPENDIX B: IN-SERVICE RATES ANALYSIS, p. 47. The MidAmerican Report had two methods of collecting data, both Web Survey and Postcard, and these values were weighted with the Cadmus survey response.

³⁰² Average of kitchen and Bathroom ISRs.

³⁰³ Based on results provided in "School-based interim process memo_Final_100215.doc."

Iowa Energy Efficiency Statewide Technical Reference Manual—2.3.4 Low Flow Faucet Aerators

Program	Faucet	Market/Program	Algorithm	ΔkWh
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0877 * 0.95$	25.3
	Bathroom	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0703 * 0.95$	35.8
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0344 * 0.95$	17.5
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0703 * 0.95$	12.9
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0703 * 0.95$	24.0
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0344 * 0.95$	11.8
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0703 * 0.95$	8.6
	Unknown	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0827 * 0.95$	54.6
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0405 * 0.95$	26.8
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0827 * 0.95$	19.7
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0827 * 0.95$	43.0
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0405 * 0.95$	21.1
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0827 * 0.95$	15.5
		Unknown Location	Assumes 80% SF and 20% MF ³⁰⁴	18.8
Efficiency Kits – Residential	Kitchen	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0877 * 0.74$	81.5
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0430 * 0.74$	40.0
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0877 * 0.74$	29.4
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0877 * 0.74$	54.7
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0430 * 0.74$	26.8
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0877 * 0.74$	19.7
	Bathroom	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0703 * 0.46$	17.3
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0344 * 0.46$	8.5
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0703 * 0.46$	6.2
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0703 * 0.46$	11.6
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0344 * 0.46$	5.7

³⁰⁴ Based on NREL ResStock Data for IA.

Iowa Energy Efficiency Statewide Technical Reference Manual—2.3.4 Low Flow Faucet Aerators

Program	Faucet	Market/Program	Algorithm	ΔkWh
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0703 * 0.46$	4.2
	Unknown	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0827 * 0.60$	34.5
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0405 * 0.60$	16.9
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0827 * 0.60$	12.4
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0827 * 0.60$	27.2
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0405 * 0.60$	13.3
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0827 * 0.60$	9.8
		Unknown Location	Assumes 80% SF and 20% MF ³⁰⁵	11.9
Efficiency Kits – Schools	Kitchen	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0877 * 0.43$	47.4
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0430 * 0.43$	23.2
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 4.5 * 2.55 * 365 * 0.75 / 1) * 0.0877 * 0.43$	17.1
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0877 * 0.43$	31.8
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0430 * 0.43$	15.6
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 4.5 * 1.71 * 365 * 0.75 / 1) * 0.0877 * 0.43$	11.4
	Bathroom	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0703 * 0.43$	16.2
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0344 * 0.43$	7.9
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 1.6 * 2.55 * 365 * 0.90 / 1) * 0.0703 * 0.43$	5.8
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0703 * 0.43$	10.9
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0344 * 0.43$	5.3
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 1.6 * 1.71 * 365 * 0.90 / 1) * 0.0703 * 0.43$	3.9
	Unknown	Single Family Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0827 * 0.43$	24.7
		Single Family Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0405 * 0.43$	12.1
		Single Family Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 9.0 * 2.55 * 365 * 0.795 / 3.83) * 0.0827 * 0.43$	8.9
		Multifamily Electric Resistance DHW	$= 1 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0827 * 0.43$	19.5
		Multifamily Heat Pump DHW	$= 1 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0405 * 0.43$	9.5

³⁰⁵ Based on NREL ResStock Data for IA.

Program	Faucet	Market/Program	Algorithm	ΔkWh
		Multifamily Unknown DHW	$= 0.3 * ((1.83 - 1.43) * 6.9 * 1.71 * 365 * 0.795 / 2.5) * 0.0827 * 0.43$	7.0
		Unknown Location	Assumes 80% SF and 20% MF ³⁰⁶	8.5

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

$$= (GPM_base * L * Household/FPH * 365 * DF * 0.469^{307}) / GPH$$

Building Type	Faucet location	Calculation	Hours per faucet
Single Family Electric Resistance DHW (or Unknown)	Kitchen	$(1.83 * 4.5 * 2.55 / 1 * 365 * 0.75 * 0.469) / 26.3$	102.5
	Bathroom	$(1.83 * 1.6 * 2.55 / 1 * 365 * 0.9 * 0.469) / 26.3$	43.7
	Unknown	$(1.83 * 9.0 * 2.55 / 3.83 * 365 * 0.795 * 0.489) / 26.3$	56.7
Single Family Heat Pump DHW	Kitchen	$(1.83 * 4.5 * 2.55 / 1 * 365 * 0.75 * 0.469) / 53.7$	50.2
	Bathroom	$(1.83 * 1.6 * 2.55 / 1 * 365 * 0.9 * 0.469) / 53.7$	21.4
	Unknown	$(1.83 * 9.0 * 2.55 / 3.83 * 365 * 0.795 * 0.469) / 53.7$	27.8
Multifamily Electric Resistance DHW (or Unknown)	Kitchen	$(1.83 * 4.5 * 1.71 / 1 * 365 * 0.75 * 0.469) / 26.3$	68.7
	Bathroom	$(1.83 * 1.6 * 1.71 / 1 * 365 * 0.9 * 0.469) / 26.3$	29.3
	Unknown	$(1.83 * 6.9 * 1.71 / 2.5 * 365 * 0.795 * 0.469) / 26.3$	44.7
Multifamily Heat Pump DHW	Kitchen	$(1.83 * 4.5 * 1.71 / 1 * 365 * 0.75 * 0.469) / 53.7$	33.7
	Bathroom	$(1.83 * 1.6 * 1.71 / 1 * 365 * 0.9 * 0.469) / 53.7$	14.4
	Unknown	$(1.83 * 6.9 * 1.71 / 2.5 * 365 * 0.795 * 0.469) / 53.7$	21.9

GPH = Gallons per hour recovery of electric water heater calculated for 68.7°F temp rise (126.5-57.8), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 4.5kW electric resistance storage tank

$$= 26.3 \text{ for electric resistance or unknown, } 53.7 \text{ for heat pump}^{308}$$

CF = Coincidence Factor for electric load reduction

$$= 1.7\%^{309}$$

³⁰⁶ Based on NREL ResStock Data for IA.

³⁰⁷ 46.9% is the proportion of hot 126.5F water mixed with 57.8F supply water to give 90F mixed faucet water.

³⁰⁸ See 'Calculation of GPH Recovery 2025.xls' for calculation details.

³⁰⁹ 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

Based on defaults provided above³¹⁰:

Program	Faucet	Market/Program	ΔkW
Direct-install, NC, or TOS	Kitchen	Single Family Electric Resistance DHW	0.0179
		Single Family Heat Pump DHW	0.0179
		Single Family Unknown DHW	0.0064
		Multifamily Electric Resistance DHW	0.0179
		Multifamily Heat Pump DHW	0.0179
		Multifamily Unknown DHW	0.0064
	Bathroom	Single Family Electric Resistance DHW	0.0143
		Single Family Heat Pump DHW	0.0143
		Single Family Unknown DHW	0.0052
		Multifamily Electric Resistance DHW	0.0143
		Multifamily Heat Pump DHW	0.0143
		Multifamily Unknown DHW	0.0052
	Unknown	Single Family Electric Resistance DHW	0.0168
		Single Family Heat Pump DHW	0.0169
		Single Family Unknown DHW	0.0061
		Multifamily Electric Resistance DHW	0.0168
		Multifamily Heat Pump DHW	0.0169
		Multifamily Unknown DHW	0.0061
		Unknown ³¹¹	0.0061
Efficiency Kits – Residential	Kitchen	Single Family Electric Resistance DHW	0.0139
		Single Family Heat Pump DHW	0.0139
		Single Family Unknown DHW	0.0050
		Multifamily Electric Resistance DHW	0.0139
		Multifamily Heat Pump DHW	0.0139
		Multifamily Unknown DHW	0.0050
	Bathroom	Single Family Electric Resistance DHW	0.0069
		Single Family Heat Pump DHW	0.0069
		Single Family Unknown DHW	0.0025
		Multifamily Electric Resistance DHW	0.0069
		Multifamily Heat Pump DHW	0.0069
		Multifamily Unknown DHW	0.0025
	Unknown	Single Family Electric Resistance DHW	0.0106
		Single Family Heat Pump DHW	0.0106
		Single Family Unknown DHW	0.0038
		Multifamily Electric Resistance DHW	0.0106
		Multifamily Heat Pump DHW	0.0106
		Multifamily Unknown DHW	0.0038
		Unknown ³¹²	0.0038
Efficiency Kits – Schools	Kitchen	Single Family Electric Resistance DHW	0.0081
		Single Family Heat Pump DHW	0.0081
		Single Family Unknown DHW	0.0029

percentage of total annual aerator use in peak period is $0.18 \times 65 / 365 = 3.20\%$. The number of hours of recovery during peak periods is therefore assumed to be $3.20\% \times 142 = 4.5$ 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 $4.5 / 260 = 0.017$.

³¹⁰ Please see the analysis file for algorithm inputs for each combination.

³¹¹ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³¹² Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

Program	Faucet	Market/Program	ΔkW
		Multifamily Electric Resistance DHW	0.0081
		Multifamily Heat Pump DHW	0.0081
		Multifamily Unknown DHW	0.0029
	Bathroom	Single Family Electric Resistance DHW	0.0065
		Single Family Heat Pump DHW	0.0065
		Single Family Unknown DHW	0.0023
		Multifamily Electric Resistance DHW	0.0065
		Multifamily Heat Pump DHW	0.0065
		Multifamily Unknown DHW	0.0023
	Unknown	Single Family Electric Resistance DHW	0.0076
		Single Family Heat Pump DHW	0.0076
		Single Family Unknown DHW	0.0027
		Multifamily Electric Resistance DHW	0.0076
		Multifamily Heat Pump DHW	0.0076
		Multifamily Unknown DHW	0.0027
		Unknown ³¹³	0.0027

NATURAL GAS SAVINGS

$$\Delta Therms = \%FossilDHW * (GPM_{base} - GPM_{low}) * L * Household * 365 * \frac{DF}{FPH} * EPG_{gas} * ISR$$

Where:

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

DHW Fuel	%FossilDHW
Electric	0%
Natural Gas	100%
Unknown	64% ³¹⁴

EPG_{gas} = Energy per gallon of hot water supplied by gas water heater

$$= (\gamma_{Water} * 1.0 * (WaterTemp - SupplyTemp)) / (RE_{gas} * 100,000)$$

= 0.0030 Therm/gal for SF or MF homes with storage tank (Bath), 0.0038 Therm/gal for SF or MF homes with storage tank (Kitchen), 0.0035 Therm/gal for SF or MF homes with storage tank (Unknown)

= 0.0040 Therm/gal for MF homes with central boiler DHW (Bath), 0.0050 Therm/gal for MF homes with central boiler DHW (Kitchen), 0.0047 Therm/gal for MF homes with central boiler DHW (Unknown)

= 0.0034 Therm/gal for MF homes with unknown DHW (Bath), 0.0042 Therm/gal for MF homes with unknown DHW (Kitchen), 0.0040 Therm/gal for MF homes with unknown DHW (Unknown)

Where:

³¹³ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³¹⁴ Default assumption for unknown fuel is based on ResStock data for the state of 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.

RE_gas = Recovery efficiency of gas water heater
 = 78% for SF homes³¹⁵
 = 78% for MF homes with storage tank, 59% if hot water through central boiler or 69% if unknown³¹⁶

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

Other variables as defined above³¹⁷:

Program	Faucet	Market/Program	ΔTherms
Direct-install, NC, or TOS	Kitchen	Single Family Gas DHW	4.5
		Single Family Unknown DHW	2.7
		Multifamily Gas Storage DHW	3.0
		Multifamily Gas Central Boiler DHW	4.0
		Multifamily Gas Unknown DHW	3.4
		Multifamily Unknown DHW	2.2
	Bathroom	Single Family Gas DHW	1.5
		Single Family Unknown DHW	1.5
		Multifamily Gas Storage DHW	0.7
		Multifamily Gas Central Boiler DHW	1.4
		Multifamily Gas Unknown DHW	1.2
		Multifamily Unknown DHW	0.7
	Unknown	Single Family Gas DHW	2.3
		Single Family Unknown DHW	1.7
		Multifamily Gas Storage DHW	1.8
		Multifamily Gas Central Boiler DHW	2.4
		Multifamily Gas Unknown DHW	2.1
		Multifamily Unknown DHW	1.3
		Unknown Location ³¹⁸	1.7
Efficiency Kits – Residential	Kitchen	Single Family Gas DHW	3.5
		Single Family Unknown DHW	2.5
		Multifamily Gas Storage DHW	2.3
		Multifamily Gas Central Boiler DHW	3.1
		Multifamily Gas Unknown DHW	2.6
		Multifamily Unknown DHW	1.7
	Bathroom	Single Family Gas DHW	0.7
		Single Family Unknown DHW	0.8
		Multifamily Gas Storage DHW	0.3
		Multifamily Gas Central Boiler DHW	0.7
		Multifamily Gas Unknown DHW	0.6
		Multifamily Unknown DHW	0.4
	Unknown	Single Family Gas DHW	1.5
		Single Family Unknown DHW	1.1

³¹⁵ 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%.

³¹⁶ 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.

³¹⁷ Please see the analysis file for algorithm inputs for each combination.

³¹⁸ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

Program	Faucet	Market/Program	ΔTherms
Efficiency Kits – Schools		Multifamily Gas Storage DHW	1.2
		Multifamily Gas Central Boiler DHW	1.5
		Multifamily Gas Unknown DHW	1.3
		Multifamily Unknown DHW	0.8
		Unknown Location ³¹⁹	1.1
	Kitchen	Single Family Gas DHW	2.0
		Single Family Unknown DHW	1.5
		Multifamily Gas Storage DHW	1.4
		Multifamily Gas Central Boiler DHW	1.8
		Multifamily Gas Unknown DHW	1.5
		Multifamily Unknown DHW	1.0
	Bathroom	Single Family Gas DHW	0.7
		Single Family Unknown DHW	0.8
		Multifamily Gas Storage DHW	0.3
		Multifamily Gas Central Boiler DHW	0.6
		Multifamily Gas Unknown DHW	0.5
		Multifamily Unknown DHW	0.3
	Unknown	Single Family Gas DHW	1.1
		Single Family Unknown DHW	0.8
		Multifamily Gas Storage DHW	0.8
		Multifamily Gas Central Boiler DHW	1.1
		Multifamily Gas Unknown DHW	0.9
		Multifamily Unknown DHW	0.6
		Unknown Location ³²⁰	0.8

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:

$$\Delta PeakTherms = \frac{\Delta Therms}{365}$$

Where:

ΔTherms = Therm impact calculated above

365 = Days per year

Program	Faucet	Market/Program	ΔPeakTherms
Direct-install, NC, or TOS	Kitchen	Single Family Gas DHW	0.0123
		Single Family Unknown DHW	0.0074
		Multifamily Gas Storage DHW	0.0082
		Multifamily Gas Central Boiler DHW	0.0109
		Multifamily Gas Unknown DHW	0.0093
		Multifamily Unknown DHW	0.0060
	Bathroom	Single Family Gas DHW	0.0042
		Single Family Unknown DHW	0.0042
		Multifamily Gas Storage DHW	0.0018

³¹⁹ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³²⁰ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

Program	Faucet	Market/Program	ΔPeakTherms
		Multifamily Gas Central Boiler DHW	0.0037
		Multifamily Gas Unknown DHW	0.0032
		Multifamily Unknown DHW	0.0020
	Unknown	Single Family Gas DHW	0.0064
		Single Family Unknown DHW	0.0046
		Multifamily Gas DHW	0.0051
		Multifamily Gas Central Boiler DHW	0.0067
		Multifamily Gas Unknown DHW	0.0057
		Multifamily Unknown DHW	0.0037
		Unknown Location ³²¹	0.0048
Efficiency Kits – Residential	Kitchen	Single Family Gas DHW	0.0096
		Single Family Unknown DHW	0.0069
		Multifamily Gas Storage DHW	0.0064
		Multifamily Gas Central Boiler DHW	0.0085
		Multifamily Gas Unknown DHW	0.0073
		Multifamily Unknown DHW	0.0046
	Bathroom	Single Family Gas DHW	0.0020
		Single Family Unknown DHW	0.0023
		Multifamily Gas Storage DHW	0.0009
		Multifamily Gas Central Boiler DHW	0.0018
		Multifamily Gas Unknown DHW	0.0015
		Multifamily Unknown DHW	0.0010
	Unknown	Single Family Gas DHW	0.0041
		Single Family Unknown DHW	0.0029
		Multifamily Gas DHW	0.0032
		Multifamily Gas Central Boiler DHW	0.0042
		Multifamily Gas Unknown DHW	0.0036
		Multifamily Unknown DHW	0.0023
		Unknown Location ³²²	0.0030
Efficiency Kits – Schools	Kitchen	Single Family Gas DHW	0.0056
		Single Family Unknown DHW	0.0040
		Multifamily Gas Storage DHW	0.0037
		Multifamily Gas Central Boiler DHW	0.0049
		Multifamily Gas Unknown DHW	0.0042
		Multifamily Unknown DHW	0.0027
	Bathroom	Single Family Gas DHW	0.0019
		Single Family Unknown DHW	0.0022
		Multifamily Gas Storage DHW	0.0008
		Multifamily Gas Central Boiler DHW	0.0017
		Multifamily Gas Unknown DHW	0.0014
		Multifamily Unknown DHW	0.0009
	Unknown	Single Family Gas DHW	0.0029
		Single Family Unknown DHW	0.0021
		Multifamily Gas DHW	0.0023
		Multifamily Gas Central Boiler DHW	0.0030
		Multifamily Gas Unknown DHW	0.0026
		Multifamily Unknown DHW	0.0017

³²¹ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³²² Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

Program	Faucet	Market/Program	Δ PeakTherms
		Unknown Location ³²³	0.0022

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Gallons = ((GPM_{base} - GPM_{low}) * L * Household * 365 * \frac{DF}{FPH}) * ISR$$

Variables as defined above³²⁴:

Program	Faucet	Market/Program	Δ Gallons
Direct-install, NC, or TOS	Kitchen	Single Family	1,194
		Multifamily	800
	Bathroom	Single Family	509
		Multifamily	342
	Unknown	Single Family	661
		Multifamily	520
		Unknown Location ³²⁵	633
Efficiency Kits – Residential	Kitchen	Single Family	930
		Multifamily	624
	Bathroom	Single Family	247
		Multifamily	165
	Unknown	Single Family	417
		Multifamily	329
Efficiency Kits – Schools	Kitchen	Single Family	540
		Multifamily	362
	Bathroom	Single Family	231
		Multifamily	155
	Unknown	Single Family	299
		Multifamily	236
		Unknown Location ³²⁷	286

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-LFFA-V08-270101

SUNSET DATE: 1/1/2029

³²³ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³²⁴ Please see the analysis file for algorithm inputs for each combination.

³²⁵ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³²⁶ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³²⁷ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

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.³²⁸

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 \$42.22.³²⁹

For time of sale or new construction, actual incremental costs may be used (assume a baseline showerhead material cost of \$14.32).³³⁰ If actual costs are unavailable, assume an incremental cost of \$14.90.³³¹

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)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note: these savings are per showerhead fixture.

³²⁸2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation," California Public Utilities Commission, January, 2014."

³²⁹Direct-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).

³³⁰ Cost of standard showerhead from California DEER Ex Ante Database.

³³¹ Incremental cost from California DEER Ex Ante Database.

$$\Delta kWh = \%ElectricDHW * (GPM_base - GPM_low) * L * Household * SPCD * \frac{365}{SPH} * EPG_electric * ISR$$

Where:

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

DHW Fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	36% ³³²

GPM_base = Flow rate of the baseline showerhead

= Actual measured flow rate. If not measured assume:

Program	GPM_base
Direct-install	2.5 ³³³
Retrofit, Efficiency Kits, NC, or TOS	2.35 ³³⁴

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 min³³⁵

Household = Average number of people per household

Household Unit Type	Household ³³⁶
Single-Family – Deemed	2.55 ³³⁷
Multifamily – Deemed	1.71 ³³⁸
Custom	Actual Occupancy or Number of Bedrooms ³³⁹

SPCD = Showers Per Capita Per Day

³³² Default assumption for unknown fuel is based on ResStock data for the state of Iowa. 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.

³³³ The Energy Policy Act of 1992 (EPA) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

³³⁴ 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.

³³⁵ 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.

³³⁶ 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.

³³⁷ NREL ResStock building characteristic data released in 2022.

³³⁸ Ibid.

³³⁹ Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

$$= 0.6^{340}$$

365 = Days per year, on average

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

Household Unit Type	SPH
Single-Family	1.79 ³⁴¹
Multifamily	1.3 ³⁴²
Custom	Actual

EPG_{electric} = Energy per gallon of hot water supplied by electric

$$= (\gamma_{\text{Water}} * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{electric}} * 3412)$$

= 0.1076 kWh/gal for resistance (or unknown) unit, 0.0527 kWh/gal for heat pump water heaters

Where:

γ_{Water} = Specific weight of water (lbs/gallon)

= 8.33 lbs/gallon

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

ShowerTemp = Assumed temperature of water

= 101°F³⁴³

SupplyTemp = Assumed temperature of water entering house

= 57.8³⁴⁴

RE_{electric} = Average Recovery efficiency of electric water heater

= 98%³⁴⁵ for electric resistance (or unknown)

= 200%³⁴⁶ for heat pump water heaters

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

³⁴⁰ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

³⁴¹ Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

³⁴² 2009 ComEd residential survey of 140 sites, provided by Cadmus.

³⁴³ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

³⁴⁴ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20. Water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. See 'Hot Water – Temps to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

³⁴⁵ Electric water heaters have recovery efficiency of 98% from the AHRI Directory.

³⁴⁶ 200% 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.

ISR = In service rate of showerhead

Program	ISR
Direct-install, NC, or TOS	0.98 ³⁴⁷
Efficiency Kits – Residential ³⁴⁸	0.47
Efficiency Kits – Schools ³⁴⁹	0.43

Based on defaults provided above³⁵⁰:

Program	Market	ΔkWh
Direct Install	Single Family Electric Resistance DHW	256.7
	Single Family Heat Pump DHW	125.8
	Single Family Unknown DHW	92.4
	Multifamily Electric Resistance DHW	237.0
	Multifamily Heat Pump DHW	116.1
	Multifamily Unknown DHW	85.3
NC or TOS	Single Family Electric Resistance DHW	218.2
	Single Family Heat Pump DHW	106.9
	Single Family Unknown DHW	78.5
	Multifamily Electric Resistance DHW	201.4
	Multifamily Heat Pump DHW	98.7
	Multifamily Unknown DHW	72.5
	Unknown Location ³⁵¹	77.3
Efficiency Kits – Residential	Single Family Electric Resistance DHW	105.3
	Single Family Heat Pump DHW	51.6
	Single Family Unknown DHW	37.9
	Multifamily Electric Resistance DHW	97.3
	Multifamily Heat Pump DHW	47.7
	Multifamily Unknown DHW	35.0
	Unknown Location ³⁵²	37.3
Efficiency Kits – LivingWise (Schools)	Single Family Electric Resistance DHW	95.7
	Single Family Heat Pump DHW	46.9
	Single Family Unknown DHW	34.5
	Multifamily Electric Resistance DHW	88.4
	Multifamily Heat Pump DHW	43.3
	Multifamily Unknown DHW	31.8
	Unknown Location ³⁵³	33.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

³⁴⁷ 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.

³⁴⁸ Based on weighted average of data collected in MidAmerican Energy Company & TetraTech "Residential Assessment Impact and Process Evaluation FINAL". December 22, 2020, APPENDIX B: IN-SERVICE RATES ANALYSIS, p. 47.

³⁴⁹ Based on results provided in "School-based interim process memo_Final_100215.doc."

³⁵⁰ Please see the analysis file for algorithm inputs for each combination.

³⁵¹ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁵² Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁵³ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

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Where:

ΔkWh = Calculated value above

Hours = Annual electric DHW recovery hours for showerhead use

$$= (GPM_base * L * Household * SPCD * 365 * 0.629^{354}) / GPH$$

Program	Building Type	Hours
Direct Install	Single Family Electric Resistance DHW (or unknown)	260.4
	Single Family Heat Pump DHW	127.6
	Multifamily Electric Resistance DHW (or unknown)	174.7
	Multifamily Heat Pump DHW	85.5
Efficiency Kits, NC and TOS	Single Family Electric Resistance DHW (or unknown)	244.8
	Single Family Heat Pump DHW	119.9
	Multifamily Electric Resistance DHW (or unknown)	164.2
	Multifamily Heat Pump DHW	80.4

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 68.7F temp rise (126.5-57.8), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 4.5kW electric resistance storage tank.

$$= 26.3 \text{ for electric resistance or unknown, } 53.7 \text{ for heat pump}^{355}$$

CF = Coincidence Factor for electric load reduction

$$= 1.6\%^{356}$$

Based on defaults provided above³⁵⁷:

Program	Market	Algorithm	ΔkWh
Direct Install	Single Family Electric Resistance DHW	$= 256.7/260.4 * 0.016$	0.0160
	Single Family Heat Pump DHW	$= 125.8/127.6 * 0.016$	0.0160
	Single Family Unknown DHW	$= 92.4/260.4 * 0.016$	0.0058
	Multifamily Electric Resistance DHW	$= 237.0/174.7 * 0.016$	0.0221
	Multifamily Heat Pump DHW	$= 116.1/85.5 * 0.016$	0.0221
	Multifamily Unknown DHW	$= 85.3/174.7 * 0.016$	0.0079
NC or TOS	Single Family Electric Resistance DHW	$= 218.2/244.8 * 0.016$	0.0145
	Single Family Heat Pump DHW	$= 106.9/119.9 * 0.016$	0.0145
	Single Family Unknown DHW	$= 78.5/244.8 * 0.016$	0.0052
	Multifamily Electric Resistance DHW	$= 201.4/164.2 * 0.016$	0.0200

³⁵⁴ 62.9% is the proportion of hot 126.5°F water mixed with 57.8°F supply water to give 101°F shower water.

³⁵⁵ See 'Calculation of GPH Recovery - 2025.xls' for calculation details.

³⁵⁶ 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 $0.11 * 65 / 365 = 1.96\%$. 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 $4.23 / 260 = 0.016$.

³⁵⁷ Please see the analysis file for algorithm inputs for each combination.

Program	Market	Algorithm	ΔkW
	Multifamily Heat Pump DHW	= 98.7/80.4 * 0.016	0.0200
	Multifamily Unknown DHW	= 72.5/164.2 * 0.016	0.0072
	Unknown location ³⁵⁸	Assumes 80% SF and 20% MF	0.0056
Efficiency Kits – Residential	Single Family Electric Resistance DHW	= 105.3/244.8 * 0.016	0.0070
	Single Family Heat Pump DHW	= 51.6/119.9 * 0.016	0.0070
	Single Family Unknown DHW	= 37.9/244.8 * 0.016	0.0025
	Multifamily Electric Resistance DHW	= 97.3/164.2 * 0.016	0.0096
	Multifamily Heat Pump DHW	= 47.7/80.4 * 0.016	0.0096
	Multifamily Unknown DHW	= 35.0/164.2 * 0.016	0.0035
	Unknown location ³⁵⁹	Assumes 80% SF and 20% MF	0.0027
Efficiency Kits – Schools	Single Family Electric Resistance DHW	= 95.7/244.8 * 0.016	0.0064
	Single Family Heat Pump DHW	= 46.9/119.9 * 0.016	0.0064
	Single Family Unknown DHW	= 34.5/244.8 * 0.016	0.0023
	Multifamily Electric Resistance DHW	= 88.4/164.2 * 0.016	0.0088
	Multifamily Heat Pump DHW	= 43.3/80.4 * 0.016	0.0088
	Multifamily Unknown DHW	= 31.8/164.2 * 0.016	0.0032
	Unknown location ³⁶⁰	Assumes 80% SF and 20% MF	0.0025

NATURAL GAS SAVINGS

$$\Delta Therms = \%FossilDHW * ((GPM_{base} - GPM_{low}) * L * Household * SPCD * \frac{365}{SPH}) * EPG_{gas} * ISR$$

Where:

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

DHW Fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	64% ³⁶¹

EPG_{gas} = Energy per gallon of hot water supplied by gas

$$= (\gamma_{Water} * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_{gas} * 100,000)$$

= 0.00461 Therm/gal for SF or MF homes with storage tanks

= 0.00610 Therm/gal for MF homes with central boiler DHW, 0.00522 Therm/gal for MF homes with unknown DHW

Where:

RE_{gas} = Recovery efficiency of gas water heater

³⁵⁸ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁵⁹ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁶⁰ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁶¹ Default assumption for unknown fuel is based on ResStock data for the state of 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.

= 78% For SF homes³⁶²

= 78% for MF homes with storage tank, 59% if hot water through central boiler or 69% if unknown³⁶³

100,000

= Converts Btus to Therms (Btu/Therm)

Other variables as defined above:³⁶⁴

Program	Market	ΔTherms
Direct Install	Single Family Gas DHW	11.0
	Single Family Unknown DHW	7.0
	Multifamily Gas Storage DHW	10.2
	Multifamily Gas Central Boiler DHW	13.4
	Multifamily Gas Unknown DHW	11.5
	Multifamily Unknown DHW	7.3
NC or TOS	Single Family Gas DHW	9.4
	Single Family Unknown DHW	6.0
	Multifamily Gas Storage DHW	8.6
	Multifamily Gas Central Boiler DHW	11.4
	Multifamily Gas Unknown DHW	9.8
	Multifamily Unknown DHW	6.2
Efficiency Kits – Residential	Unknown location ³⁶⁵	8.2
	Single Family Gas DHW	4.5
	Single Family Unknown DHW	2.9
	Multifamily Gas Storage DHW	4.2
	Multifamily Gas Central Boiler DHW	5.5
	Multifamily Gas Unknown DHW	4.7
Efficiency Kits – Schools	Multifamily Unknown DHW	3.0
	Unknown location ³⁶⁶	3.9
	Single Family Gas DHW	4.1
	Single Family Unknown DHW	2.6
	Multifamily Gas Storage DHW	3.8
	Multifamily Gas Central Boiler DHW	5.0
	Multifamily Gas Unknown DHW	4.3
	Multifamily Unknown DHW	2.7
	Unknown location ³⁶⁷	3.6

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:

$$\Delta PeakTherms = \frac{\Delta Therms}{365}$$

³⁶² 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%.

³⁶³ 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.

³⁶⁴ Please see the analysis file for algorithm inputs for each combination.

³⁶⁵ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁶⁶ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁶⁷ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

Where:

Δ Therms = Therm impact calculated above

365 = Days per year

Program	Market	Δ PeakTherms
Direct Install	Single Family Gas DHW	0.0301
	Single Family Unknown DHW	0.0193
	Multifamily Gas Storage DHW	0.0278
	Multifamily Gas Central Boiler DHW	0.0368
	Multifamily Gas Unknown DHW	0.0315
	Multifamily Unknown DHW	0.0201
NC or TOS	Single Family Gas DHW	0.0256
	Single Family Unknown DHW	0.0164
	Multifamily Gas Storage DHW	0.0237
	Multifamily Gas Central Boiler DHW	0.0313
	Multifamily Gas Unknown DHW	0.0267
	Multifamily Unknown DHW	0.0171
Efficiency Kits – Residential	Unknown location ³⁶⁸	0.0223
	Single Family Gas DHW	0.0124
	Single Family Unknown DHW	0.0079
	Multifamily Gas Storage DHW	0.0114
	Multifamily Gas Central Boiler DHW	0.0151
	Multifamily Gas Unknown DHW	0.0129
Efficiency Kits – Schools	Multifamily Unknown DHW	0.0083
	Unknown location ³⁶⁹	0.0108
	Single Family Gas DHW	0.0112
	Single Family Unknown DHW	0.0072
	Multifamily Gas Storage DHW	0.0104
	Multifamily Gas Central Boiler DHW	0.0137
	Multifamily Gas Unknown DHW	0.0117
	Multifamily Unknown DHW	0.0075
	Unknown location ³⁷⁰	0.0098

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Gallons = (GPM_{base} - GPM_{low}) * L * Household * SPCD * \frac{365}{SPH} * ISR$$

Variables as defined above:³⁷¹

Program	Market	Δ Gallons
Direct Install	Single Family	2,385
	Multifamily	2,202
NC or TOS	Single Family	2,027
	Multifamily	1,872
	Unknown Location ³⁷²	1,996

³⁶⁸ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁶⁹ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁷⁰ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁷¹ Please see the analysis file for algorithm inputs for each combination.

³⁷² Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

Program	Market	ΔGallons
Efficiency Kits – Residential	Single Family	979
	Multifamily	904
	Unknown Location ³⁷³	964
Efficiency Kits – Schools	Single Family	889
	Multifamily	821
	Unknown Location ³⁷⁴	876

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-LFSH-V08-270101

SUNSET DATE: 1/1/2029

³⁷³ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

³⁷⁴ Based on NREL ResStock Data for IA, 80% Single Family and 20% Multi Family.

2.3.6 Domestic Hot Water Pipe Insulation

DESCRIPTION

This measure applies to the addition of insulation to uninsulated domestic hot water pipes. The measure assumes the pipe wrap is installed either 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. Savings for this measure should be limited to the first 4ft of hot water pipes and 2 ft of cold water pipes. Alternatively if there is a hot water recirculating loop savings are eligible for the entire loop.

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.³⁷⁵

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,³⁷⁶ 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:

$$\Delta kWh = ((1/R_{Base} - 1/R_{EE}) * C_{Inside} * L_{effective} * \Delta T * Hours) / (\eta_{DHW_{Elec}} * 3,412)$$

Where:

- R_{Base} = Thermal resistance coefficient (hr-°F-ft²)/Btu) of uninsulated pipe
 = Varies based on pipe size and material. See table below for values.
- R_{EE} = Thermal resistance coefficient (hr-°F-ft²)/Btu) of insulated pipe

³⁷⁵ 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).

³⁷⁶ Consistent with DEER 2008 Measure Cost Summary, Revised June 2, 2008.

	= Actual ($R_{Base} + R$ value of insulation)
C_{inside}	= Inside circumference of the pipe [ft]
	= Actual (See table below for values for most common pipe sizes/materials).
$L_{effective}$	= Effective length of pipe from water heating source covered by pipe wrap (ft) ³⁷⁷
	= $L_{Horizontal} + \alpha L_{Vertical}$
	= Actual (See table below for α values). If unknown, assume 3ft of vertical and 3 ft horizontal.
ΔT	= Average temperature difference (°F) between supplied water and outside air
	= Actual or if unknown, assume 60°F ³⁷⁸
Hours	= Hours per year
	= 8,760
$\eta_{DHW_{Elec}}$	= Recovery efficiency of electric hot water heater
	= 98% ³⁷⁹ for electric resistance (or unknown)
	= 200% ³⁸⁰ for heat pump water heaters
3,412	= Conversion factor from Btu to kWh

Parameter assumptions for various pipe sizes and materials:

Type and Size	C_{inside} ³⁸¹ (I.D.* π /12) (ft)	Product of Overall Heat Transfer Coefficient and Pipe Area (UA) per foot ³⁸² from bare pipe (BTU/hr·ft·°F)	Pipe Area per linear foot (ft ²) ³⁸³	R_{exist} (hr·ft·°F)/BTU)	Horizontal to Vertical Adjustment Factor (α)
½" Copper Pipe	0.1427	0.345	0.153	0.444	0.67
¾" Copper Pipe	0.2055	0.417	0.217	0.521	0.72
½" PEX	0.1270	0.438	0.145	0.332	0.73
¾" PEX	0.1783	0.545	0.204	0.374	0.77

³⁷⁷ In cases with zero wind, heat loss (and therefore) savings is larger from horizontal pipe configurations than vertical pipe configurations due, perhaps to the way in which convective losses are handled. Given that most DHW pipe insulation installations begin with a vertical orientation from the water heater, an adjustment to the engineering calculation is needed. An analysis of the 3E PLUS tool by NAIMA yielded adjustment factors for horizontal to vertical loss and savings values. See 'PipeInsulation_3EPlus Comparison.xlsx for details of the analysis and comparisons.

³⁷⁸ Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

³⁷⁹ Electric water heaters have recovery efficiency of 98% from the AHRI Directory.

³⁸⁰ 200% 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.

³⁸¹ See: Pipe Sizing Charts Tables _ Energy-Models (last accessed 5/7/21) for copper pipe sizes and Pex Sizing(last accessed 5/7/21) for PEX pipe sizes.

³⁸² Laboratory measured values from NREL, "Hot Water System Distribution Model Enhancements," Hoeschele and Weitzel (2012), Figure 1.

³⁸³ Calculated using the average pipe thickness (I.D. + O.D.)*0.5.

For example, a home with electric DHW insulates 6 feet (4 ft vertical and 2 ft horizontal) of ¾ in copper pipe with R-3 insulation installed, with defaults from above, would save:

$$\begin{aligned}\Delta \text{kWh} &= ((1/R_{\text{Base}} - 1/R_{\text{EE}}) * C_{\text{inside}} * L_{\text{effective}} * \Delta T * \text{Hours}) / (\eta_{\text{DHW}_{\text{Elec}}} * 3,412) \\ &= ((1/0.521 - 1/3.521) * 0.2055 * (2 + 4 * 0.72) * 60 * 8,760) / (0.98 * 3,412) \\ &= 257.8 \text{ kWh}\end{aligned}$$

The following table provides annual energy savings per foot of pipe insulation for various configurations. Note these assume that the installation is verified. If programs distribute via kits an In Service Rate assumption will need to be added:

Measure Configuration	ΔkWh Savings per Foot of Insulation (kWh/ft)
Horizontal Pipe Orientation	
½" Copper Pipe insulated with R-3, ½" thick insulation	44.0
¾" Copper Pipe insulated with R-3, ½" thick insulation	52.9
½" PEX insulated with R-3, ½" thick insulation	54.2
¾" PEX insulated with R-3, ½" thick insulation	66.7
Vertical Pipe Orientation	
½" Copper Pipe insulated with R-3, ½" thick insulation	29.5
¾" Copper Pipe insulated with R-3, ½" thick insulation	38.1
½" PEX insulated with R-3, ½" thick insulation	39.5
¾" PEX insulated with R-3, ½" thick insulation	51.3
Unknown	
R-3, ½" thick insulation for ½" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	41.8
R-3, ½" thick insulation for ¾" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	52.3
Unknown pipe type (straight average) and configuration (assume 3 ft vertical and remaining horizontal) insulated with R-3, ½" thick insulation	47.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours}$$

Where:

ΔkWh = Electric energy savings from pipe wrap installation

Other variables as defined above.

For example, a home with electric DHW insulates 6 feet (4 ft vertical and 2 ft horizontal) of ¾ in copper pipe with R-3 insulation installed, with defaults from above, would save:

$$\begin{aligned}\Delta kW &= 258.0/8,760 \\ &= 0.02945 \text{ kW}\end{aligned}$$

The following table provides annual energy savings per foot of pipe insulation for various configurations. Note these assume that the installation is verified. If programs distribute via kits an In Service Rate assumption will need to be added:

Measure Configuration	ΔkW Savings per Foot of Insulation (kWh/ft)
Horizontal Pipe Orientation	
½" Copper Pipe insulated with R-3, ½" thick insulation	0.00502
¾" Copper Pipe insulated with R-3, ½" thick insulation	0.00603
½" PEX insulated with R-3, ½" thick insulation	0.00618
¾" PEX insulated with R-3, ½" thick insulation	0.00761
Vertical Pipe Orientation	
½" Copper Pipe insulated with R-3, ½" thick insulation	0.00337
¾" Copper Pipe insulated with R-3, ½" thick insulation	0.00435
½" PEX insulated with R-3, ½" thick insulation	0.00451
¾" PEX insulated with R-3, ½" thick insulation	0.00585
Unknown	
R-3, ½" thick insulation for ½" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.00477
R-3, ½" thick insulation for ¾" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.00597
Unknown pipe type (straight average) and configuration (assume 3 ft vertical and remaining horizontal) insulated with R-3, ½" thick insulation	0.00536

NATURAL GAS SAVINGS

$$\Delta Therms = ((1/R_{Base} - 1/R_{EE}) * C_{Inside} * L_{effective} * \Delta T * Hours) / (\eta_{DHW_{Gas}} * 100,000)$$

Where:

$$\begin{aligned}\eta_{DHW_{Gas}} &= \text{Recovery efficiency of gas hot water heater} \\ &= 0.78^{384} \\ 100,000 &= \text{Conversion factor from Btu to therms}\end{aligned}$$

³⁸⁴ 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%.

Other variables as defined above.

For example, a home with gas DHW insulates 6 feet (4 ft vertical and 2 ft horizontal) of ¾ in copper pipe with R-3 insulation installed, with defaults from above, would save:

$$\begin{aligned}\Delta\text{Therms} &= ((1/R_{\text{Base}} - 1/R_{\text{EE}}) * C_{\text{inside}} * L_{\text{effective}} * \Delta T * \text{Hours}) / (\eta_{\text{DHW Gas}} * 100,000) \\ &= ((1/0.521 - 1/3.521) * 0.2055 * (2 + 4 * 0.72) * 60 * 8,766) / (0.78 * 100,000) \\ &= 11.1 \text{ therms}\end{aligned}$$

The following table provides annual energy savings per foot of pipe insulation for various configurations. Note these assume that the installation is verified. If programs distribute via kits an In Service Rate assumption will need to be added:

Measure Configuration	ΔTherms Savings per Foot of Insulation (Therms/ft)
Horizontal Pipe Orientation	
½" Copper Pipe insulated with R-3, ½" thick insulation	1.89
¾" Copper Pipe insulated with R-3, ½" thick insulation	2.27
½" PEX insulated with R-3, ½" thick insulation	2.32
¾" PEX insulated with R-3, ½" thick insulation	2.86
Vertical Pipe Orientation	
½" Copper Pipe insulated with R-3, ½" thick insulation	1.26
¾" Copper Pipe insulated with R-3, ½" thick insulation	1.63
½" PEX insulated with R-3, ½" thick insulation	1.70
¾" PEX insulated with R-3, ½" thick insulation	2.20
Unknown	
R-3, ½" thick insulation for ½" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	1.79
R-3, ½" thick insulation for ¾" pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	2.24
Unknown pipe type (straight average) and configuration (assume 3 ft vertical and remaining horizontal) insulated with R-3, ½" thick insulation	2.02

PEAK GAS SAVINGS

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

$$\Delta\text{PeakTherms} = \Delta\text{Therms}/365$$

Where:

$$\begin{aligned}\Delta\text{Therms} &= \text{Gas savings from pipe wrap insulation} \\ 365 &= \text{Number of days per year}\end{aligned}$$

For example, a home with gas DHW insulates 6 ft (4 ft vertical and 2 ft horizontal) of $\frac{3}{4}$ in copper pipe with R-3 insulation installed, with defaults from above, would save:

$$\begin{aligned}\Delta\text{PeakTherms} &= 11.1/365 \\ &= 0.03041 \text{ therms}\end{aligned}$$

The following table provides annual energy savings per foot of pipe insulation for various configurations. Note these assume that the installation is verified. If programs distribute via kits an In Service Rate assumption will need to be added:

Measure Configuration	$\Delta\text{PeakTherms}$ Savings per Foot of Insulation (Therms/ft)
Horizontal Pipe Orientation	
$\frac{1}{2}$ " Copper Pipe insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00517
$\frac{3}{4}$ " Copper Pipe insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00621
$\frac{1}{2}$ " PEX insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00635
$\frac{3}{4}$ " PEX insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00783
Vertical Pipe Orientation	
$\frac{1}{2}$ " Copper Pipe insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00345
$\frac{3}{4}$ " Copper Pipe insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00446
$\frac{1}{2}$ " PEX insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00465
$\frac{3}{4}$ " PEX insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00602
Unknown	
R-3, $\frac{1}{2}$ " thick insulation for $\frac{1}{2}$ " pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.00490
R-3, $\frac{1}{2}$ " thick insulation for $\frac{3}{4}$ " pipes – pipe type and configuration unknown (assume 3 ft vertical and remaining horizontal)	0.00613
Unknown pipe type (straight average) and configuration (assume 3 ft vertical and remaining horizontal) insulated with R-3, $\frac{1}{2}$ " thick insulation	0.00553

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-PINS-V02-230101

SUNSET DATE: 1/1/2028

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.³⁸⁵

DEEMED MEASURE COST

The measure cost is the actual cost of material and installation. If actual costs are unknown, assume \$58 for material and installation.³⁸⁶

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:

$$\Delta kWh = ((1/R_{Base} - 1/R_{EE}) * A_{Base} * \Delta T * Hours) / (\eta_{DHW_{Elec}} * 3,412)$$

Where:

- A_{Base} = Surface area (ft²) of storage tank prior to adding tank wrap³⁸⁷
= Actual or if unknown, use default based on tank capacity (gal) from table below
- R_{Base} = Thermal resistance coefficient (hr-°F-ft²/BTU) of uninsulated tank
= Actual; if unknown, assume 14³⁸⁸

³⁸⁵ 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).

³⁸⁶ Average cost of R-10 tank wrap installation from the National Renewable Energy Laboratory’s National Residential Efficiency Measures Database.

³⁸⁷ Area includes tank sides and top to account for typical wrap coverage.

³⁸⁸ Baseline R-value based on information from Chapter 6 of The Virginia Energy Savers Handbook, Third Edition: The best

R_{EE}	= Thermal resistance coefficient ((hr-°F-ft ² /BTU) of tank after addition of tank wrap (R-value of uninsulated tank + R-value of tank wrap) = Actual; if unknown, assume 24
ΔT	= Average temperature difference (°F) between tank water and outside air = Actual; if unknown, assume 60°F ³⁸⁹
Hours	= Hours per year = 8,760
$\eta_{DHW_{Elec}}$	= Recovery efficiency of electric hot water heater = Actual or if unknown, assume 0.98 ³⁹⁰
3,412	= Conversion from Btu to kWh

The following table contains default savings for various tank capacities.

Capacity (gal)	A_{Base} (ft ²) ³⁹¹	ΔkWh	ΔkW
30	19.16	89.7	0.0102
40	23.18	108.5	0.0124
50	24.99	117.0	0.0133
80	31.84	149.1	0.0170

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:

$$\begin{aligned}\Delta kWh &= ((1/R_{Base} - 1/R_{EE}) * A_{Base} * \Delta T * \text{Hours}) / (\eta_{DHW_{Elec}} * 3,412) \\ &= ((1/14 - 1/24) * 19.16 * 60 * 8,760) / (0.98 * 3,412) \\ &= 89.6 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours}$$

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.

³⁸⁹ Assumes 125°F hot water tank temperature and average temperature of basement of 65°F.

³⁹⁰ Electric water heaters have recovery efficiency of 98% from the AHRI Directory.

³⁹¹ 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.

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:

$$\begin{aligned}\Delta kW &= 89.6/8,760 \\ &= 0.0102 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

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

$$\Delta Therms = ((1/R_{Base} - 1/R_{EE}) * A_{Base} * \Delta T * Hours) / (\eta_{DHW_{Gas}} * 100,000)$$

Where:

$$\begin{aligned}\eta_{DHW_{Gas}} &= \text{Recovery efficiency of gas hot water heater} \\ &= 0.78^{392}\end{aligned}$$

$$100,000 = \text{Conversion factor from Btu to therms}$$

Other variables as defined above

The following table contains default savings for various tank capacities.

Capacity (gal)	$A_{Base} \text{ (ft}^2\text{)}^{393}$	$\Delta Therms$	$\Delta PeakTherms$
30	19.16	3.8	0.0104
40	23.18	4.7	0.0129
50	24.99	5.0	0.0137
80	31.84	6.4	0.0175

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:

$$\begin{aligned}\Delta Therms &= ((1/R_{Base} - 1/R_{EE}) * A_{Base} * \Delta T * Hours) / (\eta_{DHW_{Gas}} * 100,000) \\ &= ((1/14 - 1/24) * 19.16 * 60 * 8,760) / (0.78 * 100,000) \\ &= 3.8 \text{ therms}\end{aligned}$$

PEAK GAS SAVINGS

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

$$\Delta PeakTherms = \frac{\Delta Therms}{365}$$

Where:

$$\begin{aligned}\Delta Therms &= \text{Gas savings from tanks wrap insulation} \\ 365 &= \text{Number of days per year}\end{aligned}$$

The table above contains default Peak Therm savings for various tank capacity and pre and post R-values.

³⁹² 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%.

³⁹³ 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.

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:

$$\begin{aligned}\Delta\text{PeakTherms} &= 3.8/365 \\ &= 0.0104 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-WRAP-V02-220101

SUNSET DATE: 1/1/2028

2.3.8 Drain Water Heat Recovery

DESCRIPTION

Drain Water Heat Recovery (DWHR) is a technology that captures waste heat in the drain line during a shower event, using the reclaimed heat to preheat cold water that is then delivered either to the shower or the water heater. The device can be installed in either an equal flow configuration (with preheated water being routed to both the water heater and the shower) or an unequal flow configuration (preheated water directed to either the water heater or shower). The energy harvested from a DWHR device is maximized in an equal flow configuration. It uses a non-regenerative heat exchanger to pre-heat the incoming cold fresh water with the outgoing warm drain water. It has been proven that DWHR devices only recover energy during simultaneous draws,³⁹⁴ i.e., showers, and that for energy savings purposes all other water draws can be ignored. Savings are calculated per drain water heat recovery unit. Other benefits include increased first-hour rating of water tank, improved comfort due to slower temperature degradation at run-out and reduction of coincident peak demand.³⁹⁵

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

DEFINITION OF EFFICIENT EQUIPMENT

Efficient equipment is a DWHR unit retrofitted to the main drain which includes outlets from showers, sinks and other fixtures too. Note, that the DWHR unit can either be installed in a vertical configuration or a horizontal configuration. Although, this measure covers both horizontal and vertical DWHR,³⁹⁶ the energy savings calculations focuses on vertical. Due to the lack of any moving parts, no maintenance is required for either types of DWHR units. Vertical units are said to comprise 95% of the market currently.³⁹⁷

The device can be installed in either an equal flow configuration or an unequal flow configuration. An equal flow installation is ideal with all the incoming cold water passing through the DWHR heat exchanger apparatus, after which it splits into cold water and inlet to water heater. Units should be installed in single-family homes and multi-family homes.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a storage type water heater without DWHR devices in a residential application.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 30 years.³⁹⁸

DEEMED MEASURE COST

The incremental cost for this measure is \$744 per unit.³⁹⁹

³⁹⁴ Charles Zaloum, John Gusdorf, and Anil Parekh; "Performance Evaluation of Drain Water Heat Recovery Technology at the Canadian Centre for Housing Technology", January 2007, accessed April 2020.

³⁹⁵ G.Proskiw, "Technology Profile: Residential Greywater Heat Recovery Systems", June 1998, accessed April 2020.

³⁹⁶ 2019 Title 24, Part 6 CASE Report. "Drain Water Heat Recovery – Final Report."

³⁹⁷ Ibid

³⁹⁸ Codes and Standards Enhancement (CASE) Initiative, 2019 California Building Energy Efficiency Standards, Title 24, Part 6 Report. "Drain Water Heat Recovery - Final Report." Published July 2017.

³⁹⁹ 2019 Title 24, Part 6 CASE Report. "Drain Water Heat Recovery – Final Report.", average of 4 ft and 5 ft units. Page 21.

LOADSHAPE

Loadshape RE04 – Residential Multifamily Water Heat

Loadshape RE12 – Residential Single-Family Water Heat

Loadshape RG07 – Residential Water Heat (gas)

Algorithm**CALCULATION OF SAVINGS****ELECTRIC ENERGY SAVINGS**

For electric water heating, annual energy savings per unit are calculated through the following formula:

$$\Delta kWh = \frac{(ShowerTemp - SupplyTemp) \times 8.33 \frac{BTU}{gal \cdot ^\circ F} \times GPM \times T_{shower-length} \times Household \times N_{units} \times SPCD \times 365 \frac{days}{yr} \times SF}{3412 \frac{BTU}{kWh} \times RE}$$

Where:

ShowerTemp	= assumed water temperature during shower = 101°F ⁴⁰⁰
SupplyTemp	= assumed temperature of cold water entering house = 57.8°F ⁴⁰¹
8.33	= Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
GPM	= gallon per minute, flow rate of showerhead = 2.35 Gallon/minute ⁴⁰²
T _{shower-length}	= shower length in minutes = 7.8 minutes ⁴⁰³
Household	= average number of people per household

Household Unit Type	Household ⁴⁰⁴
Single-Family – Deemed	2.55 ⁴⁰⁵

⁴⁰⁰ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

⁴⁰¹ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20. Water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. See 'Hot Water – Temps to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

⁴⁰² Current Iowa Technical Reference Manual, section 2.3.5, low flow showerheads, for Retrofit and New Construction

⁴⁰³ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and Multifamily homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

⁴⁰⁴ 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.

⁴⁰⁵ NREL ResStock building characteristic data released in 2022.

Household Unit Type	Household ⁴⁰⁴
Multifamily – Deemed	1.71 ⁴⁰⁶
Custom	Actual Occupancy or Number of Bedrooms ⁴⁰⁷

N_{units} = Number of units in a multifamily building with drains connected to the DWHR unit

Household Unit	N_{units}
Single-Family	1
Multi-Family	1 or Actual

SPCD = Showers Per Capita Per Day

= 0.6⁴⁰⁸

365 = Days per year, on average.

SF = Water heating energy savings factor

= 0.466⁴⁰⁹

3,412 = Conversion factor, 1 kWh equals 3,412 BTU

RE = Recovery efficiency of electric water heater:

= Actual or:

= 98%⁴¹⁰ for Electric Resistance (or unknown)

= 200%⁴¹¹ for Electric HPWH

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = $\Delta kWh/Hours * CF$

Where:

ΔkWh = calculated value from above.

Hours = Annual electric DHW recovery hours for showerhead use

⁴⁰⁶ Ibid.

⁴⁰⁷ 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.

⁴⁰⁸ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

⁴⁰⁹ Codes and Standards Enhancement (CASE) Initiative, 2019 California Building Energy Efficiency Standards, Title 24, Part 6 Report. "Drain Water Heat Recovery - Final Report." July 2017, pg 17.

⁴¹⁰ Electric water heaters have recovery efficiency of 98% from the AHRI Directory.

⁴¹¹ 200% 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.

$$= ((\text{GPM} \times T_{\text{shower-length}}) \times \text{Household} \times \text{SPCD} \times 365) \times 0.629^{412} / \text{GPH}$$

$$= 244.8 \text{ for Single Family Electric Resistance (or unknown)}$$

$$= 119.9 \text{ for Single Family Heat Pump Water Heater}$$

$$= 164.2 \text{ for Multifamily Electric Resistance (or unknown)}$$

$$= 80.4 \text{ for Multifamily Heat Pump Water Heater}$$

Use Multifamily if: Building meets utility's definition for multifamily

GPH = Gallons per hour recovery of electric water heater calculated for 68.7°F temp rise (126.5-57.8), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 4.5kW electric resistance storage tank.

$$= 26.3 \text{ for electric resistance or unknown, } 53.7 \text{ for heat pumps}^{413}$$

CF = Coincidence Factor for electric load reduction

$$= 1.6\%^{414}$$

NATURAL GAS SAVINGS

For gas water heating, annual energy savings per unit are calculated through the following formula:

$$\Delta \text{therms} = \frac{(\text{ShowerTemp} - \text{SupplyTemp}) \times 8.33 \frac{\text{BTU}}{\text{gal} \cdot ^\circ\text{F}} \times \text{GPM} \times T_{\text{shower-length}} \times N_{\text{persons}} \times N_{\text{units}} \times \text{SPCD} \times 365 \frac{\text{days}}{\text{yr}} \times \text{SF}}{100,000 \frac{\text{BTU}}{\text{therm}} \times \text{RE}}$$

Where:

100,000 = Conversion factor, 1 therm equals 100,000 BTU

RE = efficiency of gas water heater

= 78% for single family and multifamily with storage tank⁴¹⁵

= 59% for multifamily if hot water through central boiler, or 69% if unknown⁴¹⁶

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁴¹² 62.9% is the proportion of hot 126.5°F water mixed with 57.8°F supply water to give 101°F shower water.

⁴¹³ See 'Calculation of GPH Recovery - 2025.xls' for calculation details.

⁴¹⁴ Assume coincidence factor for DWHR units is the same with that of low flow showerheads (see Iowa Technical Reference Manual, section 2.3.5, low flow showerheads)

⁴¹⁵ 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%.

⁴¹⁶ 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.

MEASURE CODE: RS-HWE-DWHR-V01-260101

SUNSET DATE: 1/1/2029

2.3.9 Residential Shower Timer

DESCRIPTION

The shower timer provides a reminder, either visually or auditorily, to the user regarding the length of their shower. Use of a shower timer makes it easier for people to take shorter showers more consistently, which results in both water and energy savings.

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

DEFINITION OF EFFICIENT EQUIPMENT

The shower timer should provide a reminder, either visually or auditorily, to the user to keep showers to a length of 5 minutes or less.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is no shower timer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected lifetime of this measure is 2 years.⁴¹⁷

DEEMED MEASURE COST

The actual program implementation costs should be used.

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

$$\Delta \text{kWh} = \% \text{Electric}_{\text{DHW}} * \text{GPM} * (L_{\text{base}} - L_{\text{timer}}) * \text{Household} * 365 * \text{SPCD} * \text{UsageFactor} * \text{EPG}_{\text{Electric}}$$

Where:

$\% \text{Electric}_{\text{DHW}}$ = proportion of water heating supplied by electric resistance heating

DHW Fuel	$\% \text{Electric}_{\text{DHW}}$
Electric	100%
Fossil Fuel	0%
Unknown	36% ⁴¹⁸

GPM = Flow rate of showerhead as used

⁴¹⁷ Estimate of persistence of behavior change instigated by the shower timer.

⁴¹⁸ Default assumption for unknown fuel is based on ResStock data for the state of Iowa. 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.

= Custom, to be determined through evaluation. If data is not available, use 1.93⁴¹⁹

L_base = Shower length in minutes without a shower timer

= 7.8 minutes⁴²⁰

L_timer = Shower length in minutes with a shower timer

= Custom, to be determined through evaluation. If data is not available, use 5.79⁴²¹

Household = Number of people in household using shower timer

Household Unit Type	Household ⁴²²
Single-Family – Deemed	2.55 ⁴²³
Multifamily – Deemed	1.71 ⁴²⁴
Custom	Actual Occupancy or Number of Bedrooms ⁴²⁵

365 = Days per year, on average

SPCD = Showers Per Capita Per Day

= 0.6⁴²⁶

UsageFactor = How often each participant uses shower time

= custom, to be determined through evaluation. If data is not available, use 0.34⁴²⁷

EPG_electric = Energy per gallon of hot water supplied by electric

= $(\gamma\text{Water} * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE_electric} * 3,412)$

= 0.1076 kWh/gal for resistance (or unknown) unit, 0.0527 kWh/gal for heat pump water heaters

Where:

γWater = Specific weight of water (lbs/gallon)

⁴¹⁹ Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

⁴²⁰ 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.

⁴²¹ Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

⁴²² 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.

⁴²³ NREL ResStock building characteristic data released in 2022.

⁴²⁴ Ibid.

⁴²⁵ 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.

⁴²⁶ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

⁴²⁷ Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

= 8.33 lbs/gallon

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

ShowerTemp = Assumed temperature of water

= 101°F⁴²⁸

SupplyTemp = Assumed temperature of water entering house

= 57.8⁴²⁹

RE_electric = Average Recovery efficiency of electric water heater

= 98%⁴³⁰ for electric resistance (or unknown)

= 200%⁴³¹ for heat pump water heaters

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for showerhead use

$$= (\text{GPM_base} * \text{L_base} * \text{Household} * \text{SPCD} * \text{UsageFactor} * 365) * 0.629^{432} / \text{GPH}$$

GPH = Gallons per hour recovery of electric water heater calculated for 68.7°F temp rise (126.5-57.8), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 4.5kW electric resistance storage tank.

= 26.3 for electric resistance or unknown, 53.7 for heat pump⁴³³

⁴²⁸ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

⁴²⁹ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20. Water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. See 'Hot Water – Temps to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

⁴³⁰ Electric water heaters have recovery efficiency of 98% from the AHRI Directory.

⁴³¹ 200% 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.

⁴³² 62.9% is the proportion of hot 126.5°F water mixed with 57.8°F supply water to give 101°F shower water.

⁴³³ See 'Calculation of GPH Recovery - 2025.xls' for calculation details.

CF = Coincidence Factor for electric load reduction

$$= 1.6\%^{434}$$

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \% \text{FossilDHW} * \text{GPM} * (\text{L}_{\text{base}} - \text{L}_{\text{timer}}) * \text{Household} * \text{Days/yr} * \text{SPCD} * \text{UsageFactor} * \text{EPG}_{\text{Gas}}$$

Where:

$\% \text{FossilDHW}$ = Proportion of water heating supplied by Natural Gas heating

DHW Fuel	$\% \text{Fossil}_{\text{DHW}}$
Electric	0%
Fossil Fuel	100%
Unknown	64% ⁴³⁵

EPG_{gas} = Energy per gallon of hot water supplied by gas

$$= (\gamma_{\text{Water}} * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{gas}} * 100,000)$$

$$= 0.00461 \text{ Therm/gal for SF or MF homes with storage tanks}$$

$$= 0.00610 \text{ Therm/gal for MF homes with central boiler DHW, } 0.00522 \text{ Therm/gal for MF homes with unknown DHW}$$

Where:

RE_{gas} = Recovery efficiency of gas water heater

$$= 78\% \text{ For SF homes}^{436}$$

$$= 78\% \text{ for MF homes with storage tank, } 59\% \text{ if hot water through central boiler or } 69\% \text{ if unknown}^{437}$$

$$100,000 = \text{Converts Btus to Therms (Btu/Therm)}$$

Other variables as defined above.

⁴³⁴ 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 $0.11 * 65 / 365 = 1.96\%$. 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 $4.23 / 260 = 0.016$.

⁴³⁵ Default assumption for unknown fuel is based on ResStock data for the state of 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.

⁴³⁶ 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%.

⁴³⁷ 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.

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:

$$\Delta\text{PeakTherms} = \Delta\text{Therms}/365$$

Where:

$$\Delta\text{Therms} = \text{Therm impact calculated above}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta\text{Gallons} = \text{GPM} * (\text{L_base} - \text{L_timer}) * \text{Household} * 365 * \text{SPCD} * \text{UsageFactor}$$

Other variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-RSTM-V01-260101

SUNSET DATE: 1/1/2029

2.3.10 Residential Thermostatic Shower Valve

DESCRIPTION

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

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

DEFINITION OF EFFICIENT EQUIPMENT

Efficient equipment for this measure is a residential showerhead with a thermostatic restrictor shower valve installed.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a residential showerhead without a restrictor valve installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected lifetime for this measure is 10 years.⁴³⁸

DEEMED MEASURE COST

The incremental cost of the measure should be the actual program cost (including labor if applicable).

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

$$\Delta kWh = \%ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365 / SPH) * EPG_electric * ISR$$

Where:

$\%Electric\ DHW$ = proportion of water heating supplied by electric resistance heating

DHW Fuel	$\%Electric_DHW$
Electric	100%
Fossil Fuel	0%

⁴³⁸ Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead.

Unknown	36% ⁴³⁹
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GPM = Flow rate of the baseline showerhead

= Actual measured flow rate. If not measured assume:

Program	GPM_base
Direct-install	2.5 ⁴⁴⁰
Retrofit, Efficiency Kits, NC, or TOS	2.35 ⁴⁴¹

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve = 0.89 minutes⁴⁴²

Household = Number of people in household using shower timer

Household Unit Type	Household ⁴⁴³
Single-Family – Deemed	2.55 ⁴⁴⁴
Multifamily – Deemed	1.71 ⁴⁴⁵
Custom	Actual Occupancy or Number of Bedrooms ⁴⁴⁶

365 = Days per year, on average

SPCD = Showers Per Capita Per Day

= 0.6⁴⁴⁷

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

Household Unit Type	SPH
Single-Family	1.79 ⁴⁴⁸
Multifamily	1.3 ⁴⁴⁹

⁴³⁹ Default assumption for unknown fuel is based on ResStock data for the state of Iowa. 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.

⁴⁴⁰ The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

⁴⁴¹ 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.

⁴⁴² Average of the following sources: ShowerStart LLC survey; “Identifying, Quantifying and Reducing Behavioral Waste in the Shower: Exploring the Savings Potential of ShowerStart”, City of San Diego Water Department survey; “Water Conservation Program: ShowerStart Pilot Project White Paper”, and PG&E Work Paper PGECODHW113.

⁴⁴³ 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.

⁴⁴⁴ NREL ResStock building characteristic data released in 2022.

⁴⁴⁵ Ibid.

⁴⁴⁶ 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.

⁴⁴⁷ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

⁴⁴⁸ Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

⁴⁴⁹ 2009 ComEd residential survey of 140 sites, provided by Cadmus.

Custom	Actual
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EPG_{electric} = Energy per gallon of hot water supplied by electric

$$= (\gamma_{\text{Water}} * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{electric}} * 3412)$$

$$= 0.1076 \text{ kWh/gal for resistance (or unknown) unit, } 0.0527 \text{ kWh/gal for heat pump water heaters}$$

Where:

γ_{Water} = Specific weight of water (lbs/gallon)

$$= 8.33 \text{ lbs/gallon}$$

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

ShowerTemp = Assumed temperature of water

$$= 101^{\circ}\text{F}^{450}$$

SupplyTemp = Assumed temperature of water entering house

$$= 57.8^{451}$$

RE_{electric} = Average Recovery efficiency of electric water heater

$$= 98\%^{452} \text{ for electric resistance (or unknown)}$$

$$= 200\%^{453} \text{ for heat pump water heaters}$$

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

ISR = In service rate of showerhead

Program	ISR
Direct-install, NC, or TOS	0.98 ⁴⁵⁴
Efficiency Kits – Residential ⁴⁵⁵	0.47

⁴⁵⁰ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

⁴⁵¹ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg. 19-20. Water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. See 'Hot Water – Temps to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

⁴⁵² Electric water heaters have recovery efficiency of 98% from the AHRI Directory.

⁴⁵³ 200% 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.

⁴⁵⁴ 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.

⁴⁵⁵ Based on weighted average of data collected in MidAmerican Energy Company & TetraTech "Residential Assessment Impact and Process Evaluation FINAL". December 22, 2020, APPENDIX B: IN-SERVICE RATES ANALYSIS, p. 47.

Efficiency Kits – Schools ⁴⁵⁶	0.43
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SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for showerhead use

$$= (\text{GPM}_{\text{base}} * L_{\text{base}} * \text{Household} * \text{SPCD} * \text{UsageFactor} * 365) * 0.629^{457} / \text{GPH}$$

GPH = Gallons per hour recovery of electric water heater calculated for 68.7F temp rise (126. – 57.8), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

$$= 26.3 \text{ for electric resistance or unknown, } 53.7 \text{ for heat pump}^{458}$$

CF = Coincidence Factor for electric load reduction

$$= 1.6\%^{459}$$

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \% \text{FossilDHW} * ((\text{GPM}_{\text{base_S}} * L_{\text{showerdevice}}) * \text{Household} * \text{SPCD} * 365 / \text{SPH}) * \text{EPG}_{\text{gas}} * \text{ISR}$$

Where:

EPG_{gas} = Energy per gallon of hot water supplied by gas

$$= (\gamma \text{Water} * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{gas}} * 100,000)$$

$$= 0.00461 \text{ Therm/gal for SF or MF homes with storage tanks}$$

$$= 0.00610 \text{ Therm/gal for MF homes with central boiler DHW, } 0.00522 \text{ Therm/gal for MF homes with unknown DHW}$$

Where:

$$\text{RE}_{\text{gas}} = \text{Recovery efficiency of gas water heater}$$

⁴⁵⁶ Based on results provided in "School-based interim process memo_Final_100215.doc."

⁴⁵⁷ 62.9% is the proportion of hot 126.5°F water mixed with 57.8°F supply water to give 101°F shower water.

⁴⁵⁸ See 'Calculation of GPH Recovery - 2025.xls' for calculation details.

⁴⁵⁹ 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 $0.11 * 65 / 365 = 1.96\%$. 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 $4.23 / 260 = 0.016$.

= 78% For SF homes⁴⁶⁰

= 78% for MF homes with storage tank, 59% if hot water through central boiler or 69% if unknown⁴⁶¹

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

Other variables as defined above.

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:

$$\Delta \text{PeakTherms} = \Delta \text{Therms} / 365$$

Where:

ΔTherms = Therm impact calculated above

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta \text{Gallons} = ((\text{GPM_base_S} * \text{L_showerdevice}) * \text{Household} * \text{SPCD} * 365 / \text{SPH}) * \text{ISR}$$

Other variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HWE-TRSV-V01-260101

SUNSET DATE: 1/1/2029

⁴⁶⁰ Review of AHRI Directory suggests a range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

⁴⁶¹ 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.

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 ($\leq 65,000$ 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 SEER2 ≤ 9.6 . “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: SEER2 ≤ 9.6 (≤ 10 SEER) 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.

For heat pumps systems that are mix-ducted, i.e. ductless air handlers are installed in combination with a centrally ducted evaporator, it is recommended to apply this characterization.

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 ($\leq 65,000$ Btu/hr) central air source heat pump with specifications to be determined by program.

The measure characterization recommends sourcing the efficiency specifications from the actually installed equipment. If those values are not known, the default equipment efficiency recommendations are based on ENERGY STAR⁴⁶² specifications v6.2, effective January 1, 2023. The specifications require heat pumps to meet the following minimum efficiency requirements:

- Split system heat pump – 15.2 SEER2 and 7.8 HSPF2
- Single-package heat pump – 15.2 SEER2 and 7.2 HSPF2

⁴⁶² In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

- Cold Climate heat pump – 15.2 SEER2 and 8.1 HSPF2

DEFINITION OF BASELINE EQUIPMENT

Time of Sale: The baseline is a new residential sized ($\leq 65,000$ Btu/hr) central air source heat pump meeting federal standards.

New Federal Standards affecting heat pumps became effective January 1, 2023. The new standards effective in 2023, require any residential heat pump manufactured in, or imported into, the United States to have a minimum efficiency rating meeting the following:⁴⁶³

- Split system heat pump – 14.3 SEER2 and 7.5 HSPF2
- Single-package heat pump – 13.4 SEER2 and 6.7 HSPF2

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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected equipment measure life is assumed to be 18 years.⁴⁶⁴ 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.⁴⁶⁵

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on the capacity of the new unit. The actual installed cost of the central air source heat pump should be used minus the assumed installation cost of the baseline equipment from table below for electric equipment, or assume (\$1,421 + \$2930) for a new baseline 80% AFUE furnace⁴⁶⁶ or (\$1,820 + \$4,260) for a new baseline 84% AFUE boiler.⁴⁶⁷

⁴⁶³ The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and HSPF2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system heat pumps are 15 SEER and 8.8 HSPF and for single-package heat pumps are 14 SEER and 8 HSPF, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservation Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048.

⁴⁶⁴ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

⁴⁶⁵ Assumed to be one third of effective useful life.

⁴⁶⁶ Furnace costs based upon MidAmerican program data from the 2024 and 2025 program years. Baseline and labor costs are interpolated from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs are presented after baseline costs so that they may be easily distinguished as needed. See "Res HVAC Cost Update 2026" for more details.

⁴⁶⁷ Boiler baseline and labor costs are interpolated from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs are presented after baseline costs so that they may be easily distinguished as needed. See "Res HVAC Cost Update 2026" for more details.

Baseline Equipment Type	Capacity Range	Baseline Cost (\$/ton) ⁴⁶⁸
Centrally Ducted Air Source Heat Pumps	< 2 tons	(\$4,627 + \$900)
	≥ 2 to < 3 tons	(\$3,526 + \$900)
	≥ 3 to < 4 tons	(\$2,509 + \$900)
	≥ 4 tons	(\$2,177 + \$900)
Ductless Minisplit Heat Pumps	< 1 ton	(\$2,982 + \$900)
	≥ 1 to < 2 tons	(\$2,201 + \$900)
	≥ 2 to < 3 tons	(\$1,847 + \$900)
	≥ 3 tons	(\$1,135 + \$900)
Central Air Conditioning	< 2 tons	(\$1,813 + \$803)
	≥ 2 to < 3 tons	(\$2,290 + \$803)
	≥ 3 to < 4 tons	(\$2,046 + \$803)
	≥ 4 tons	(\$2,580 + \$803)

Default full cost of the efficient Centrally Ducted ASHP is provided in the table below:

Capacity Range	Full Install Cost (\$/ton) ⁴⁶⁹
< 2 tons	(\$4,715 + (\$600 * (HSPF2 - 7.8)) + \$900)
≥ 2 to < 3 tons	(\$3,593 + (\$600 * (HSPF2 - 7.8)) + \$900)
≥ 3 to < 4 tons	(\$2,557 + (\$600 * (HSPF2 - 7.8)) + \$900)
≥ 4 tons	(\$2,219 + (\$600 * (HSPF2 - 7.8)) + \$900)

The incremental cost of the Centrally Ducted ASHP compared to a baseline minimum efficiency Centrally Ducted ASHP is provided in the table below:

Capacity Range	Incremental Cost (\$/ton) ⁴⁷⁰
< 2 tons	(\$88 + (\$600 * (HSPF2 - 7.8)))

⁴⁶⁸ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Baseline costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See “Res HVAC Cost Update 2026” for more details.

⁴⁶⁹ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Additive efficiency costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See “Res HVAC Cost Update 2026” for more details.

⁴⁷⁰ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Additive efficiency costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. See “Res HVAC Cost Update 2026” for more details.

Capacity Range	Incremental Cost (\$/ton) ⁴⁷⁰
≥ 2 to < 3 tons	$(\$67 + (\$600 * (\text{HSPF2} - 7.8)))$
≥ 3 to < 4 tons	$(\$48 + (\$600 * (\text{HSPF2} - 7.8)))$
≥ 4 tons	$(\$42 + (\$600 * (\text{HSPF2} - 7.8)))$

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, refer to defaults provided above.

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is presented in the table below for electric equipment or assume (\$1,421 + \$2930) for a new baseline 80% AFUE furnace⁴⁷¹ or (\$1,820 + \$4,260) for a new baseline 84% AFUE boiler.⁴⁷² This cost should be discounted to present value using the utilities' discount rate.⁴⁷³

Baseline Equipment Type	Capacity Range	Deferred Baseline Cost (\$/ton) ⁴⁷⁴
Centrally Ducted Air Source Heat Pumps	< 2 tons	$(\$4,627 + \$900)$
	≥ 2 to < 3 tons	$(\$3,526 + \$900)$
	≥ 3 to < 4 tons	$(\$2,509 + \$900)$
	≥ 4 tons	$(\$2,177 + \$900)$
Ductless Minisplit Heat Pumps	< 1 ton	$(\$2,982 + \$900)$
	≥ 1 to < 2 tons	$(\$2,201 + \$900)$
	≥ 2 to < 3 tons	$(\$1,847 + \$900)$
	≥ 3 tons	$(\$1,135 + \$900)$
Central Air Conditioning	< 2 tons	$(\$1,813 + \$803)$

⁴⁷¹Furnace costs based upon MidAmerican program data from the 2024 and 2025 program years. Baseline and labor costs are interpolated from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs are presented after baseline costs so that they may be easily distinguished as needed. See "Res HVAC Cost Update 2026" for more details.

⁴⁷²Boiler baseline and labor costs are interpolated from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs are presented after baseline costs so that they may be easily distinguished as needed. See "Res HVAC Cost Update 2026" for more details.

⁴⁷³ Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.

⁴⁷⁴ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Baseline costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See "Res HVAC Cost Update 2026" for more details.

Baseline Equipment Type	Capacity Range	Deferred Baseline Cost (\$/ton) ⁴⁷⁴
	≥ 2 to < 3 tons	(\$2,290 + \$803)
	≥ 3 to < 4 tons	(\$2,046 + \$803)
	≥ 4 tons	(\$2,580 + \$803)

Quality Installation: The additional design and installation work associated with quality installation has been estimated to add \$150 to the installed cost.⁴⁷⁵

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{(SEER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] + \left[\frac{EFLH_{heat} * Capacity_{heat} * HeatLoadFactor * \left(\frac{1}{(HSPF2_{base} * (1 - DeratingHeat_{base}))} - \frac{1}{(HSPF2_{ee} * PD_{Adj} * (1 - DeratingHeat_{eff}))} \right)}{1,000} \right]$$

Early replacement:⁴⁷⁶

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

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{(SEER2_{exist} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] + \left[\frac{EFLH_{heat} * Capacity_{heat} * HeatLoadFactor * \left(\frac{1}{(HSPF2_{exist} * (1 - DeratingHeat_{base}))} - \frac{1}{(HSPF2_{ee} * PD_{Adj} * (1 - DeratingHeat_{eff}))} \right)}{1,000} \right]$$

ΔkWh for remaining measure life (next 12 years):

⁴⁷⁵ Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers; see 'Iowa HVAC Incremental Cost Study' for details.

⁴⁷⁶ 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).

Iowa Energy Efficiency Statewide Technical Reference Manual—2.4.1 Central Air Source Heat Pump

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{(SEER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] + \left[\frac{EFLH_{heat} * Capacity_{heat} * HeatLoadFactor * \left(\frac{1}{(HSPF2_{base} * (1 - DeratingHeat_{base}))} - \frac{1}{(HSPF2_{ee} * PD_{Adj} * (1 - DeratingHeat_{eff}))} \right)}{1,000} \right]$$

Where:

$EFLH_{cool}$ = Equivalent Full Load Hours of air conditioning
 = Dependent on location and building type.⁴⁷⁷ If climate zone and building type is unknown, assume 824 hours.⁴⁷⁸

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)	583	977	537	784	541	921
Zone 6 (Mason City)	291	489	268	392	271	461
Average/Unknown	514	861	472	690	477	811

$Capacity_{cool}$ = Cooling output capacity of Air Source Heat Pump (Btu/hr), rated at A2 conditions, 95°F outdoor dry-bulb temperature.

= Actual (where 1 ton = 12,000 Btu/hr); if unknown assume 34,281 Btu/hr⁴⁷⁹

$SEER2_{base}$ = Seasonal Energy Efficiency Ratio 2 (SEER2) of baseline Air Source Heat Pump (kBtu/kWh)
 = 14.3 SEER2 (15 SEER)⁴⁸⁰

$SEER2_{ee}$ = Seasonal Energy Efficiency Ratio 2 (SEER2) of efficient Air Source Heat Pump (kBtu/kWh)
 = Actual; if unknown assume 15.2 SEER2 (16.0 SEER)⁴⁸¹

$SEER2_{exist}$ = Seasonal Energy Efficiency Ratio 2 (SEER2) of existing cooling system (kBtu/kWh)
 = Use actual SEER2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to

⁴⁷⁷ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁴⁷⁸ Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022.

⁴⁷⁹ Based on review of all available models on AHRI directory on 04/01/2022. See 'AHRI_20220401_USHP.xlsx' for more detail.

⁴⁸⁰ The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and HSPF2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system heat pumps are 15 SEER and 8.8 HSPF and for single-package heat pumps are 14 SEER and 8 HSPF, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservation Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048.

⁴⁸¹ ENERGY STAR version 6.2, effective January 1, 2023.

account for degradation over time. ⁴⁸² If unknown assume:

Existing Cooling System	SEER _{exist} ⁴⁸³	SEER2 _{exist}
Air Source Heat Pump	9.12	8.66
Central AC	8.60	8.2
Room AC	8.0	7.6
No central cooling ⁴⁸⁴	Set '1/SEER _{exist} ' = 0	Set '1/SEER2 _{exist} ' = 0
For new space conditioning, assume baseline Air Source Heat Pump	15	14.3

DeratingCool_{eff} = Efficient ASHP Cooling derating

= 0% if Quality Installation is performed

= 10.5% if Quality Installation is not performed or unknown whether it was performed (e.g. midstream program)⁴⁸⁵

DeratingCool_{base} = Baseline ASHP Cooling derating

= 10.5%⁴⁸⁶

EFLH_{Heat} = Equivalent Full Load Hours of heating

= Dependent on location and building type.⁴⁸⁷ If climate zone and building type is unknown, assume 2,229 hours.⁴⁸⁸

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)	1,892	1,991	1,367	1,618	1,769	2,104
Zone 6 (Mason City)	2,717	2,858	1,964	2,322	2,540	3,020
Average/Unknown	2,143	2,254	1,549	1,832	2,003	2,382

Capacity_{Heat} = Heating output 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 = 12,000 Btu/hr) , if unknown assume 33,842 Btu/hr⁴⁸⁹

⁴⁸² Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

⁴⁸³ 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. Converted to SEER2.

⁴⁸⁴ 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.

⁴⁸⁵ Based on Cadmus assumption in IPL TRM— results in a QI savings that is within a feasible range.

⁴⁸⁶ Ibid

⁴⁸⁷ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁴⁸⁸ Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022.

⁴⁸⁹ Based on review of all available models on AHRI directory on 04/01/2022. See 'AHRI_20220401_USHP.xlsx' for more detail.

HeatLoadFactor = Portion of HeatLoad displaced by ASHP in partial displacement applications. Varies by Switchover Temperature and Climate Region. If Switchover Temperature is unknown, use 26F.⁴⁹⁰
 = 1.0 If cold climate heat pump
 = 1.0 if full displacement, or if Switchover Temperature is lower than 17F

Climate Zone (City Based Upon)	HeatLoadFactor (by Switchover Temperature)										
	47°F	44°F	41°F	38°F	35°F	32°F	29°F	26°F	23°F	20°F	17°F
Zone 5 (Burlington)	8%	14%	20%	26%	39%	52%	59%	71%	79%	82%	89%
Zone 6 (Mason City)	6%	11%	15%	19%	25%	33%	35%	43%	49%	54%	61%
Average/Unknown	7%	12%	17%	22%	34%	46%	50%	59%	66%	71%	78%

HSPF2_{Base} = Heating System Performance Factor 2 (HSPF) of baseline Air Source Heat Pump (kBtu/kWh)
 = 7.5 HSPF2 (8.8 HSPF)⁴⁹¹

HSPF2_{ee} = Heating System Performance Factor 2 (HSPF2) of efficient Air Source Heat Pump (kBtu/kWh)
 = Actual. If unknown assume 7.8 HSPF2 (9.2 HSPF)⁴⁹²

PD_{Adj} = Adjustment multiplier to account for increased heat pump efficiency in Partial Displacement applications when there is no electric resistance backup and Switchover Temperature is higher than 17°F. Varies by Switchover Temperature and Climate Region. If Switchover Temperature is unknown, use 26F.⁴⁹³
 = 1.0 If cold climate heat pump
 = 1.0 if full displacement, or if Switchover Temperature is lower than 17F

Climate Zone (City Based Upon)	PD _{Adj} (by Switchover Temperature)										
	47°F	44°F	41°F	38°F	35°F	32°F	29°F	26°F	23°F	20°F	17°F
Zone 5 (Burlington)	155%	151%	147%	145%	140%	136%	134%	131%	129%	128%	126%
Zone 6 (Mason City)	155%	151%	148%	145%	142%	137%	136%	132%	129%	127%	124%
Average/Unknown	155%	151%	148%	145%	139%	136%	135%	132%	129%	128%	125%

HSPF2_{Exist} = Heating System Performance Factor 2 (HSPF2) of existing heating system (kBtu/kWh)
 = Use actual HSPF2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to

⁴⁹⁰ As modeled in 'ASHP Partial Displacement Analysis 20240523.xlsx'

⁴⁹¹ The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and HSPF2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system heat pumps are 15 SEER and 8.8 HSPF and for single-package heat pumps are 14 SEER and 8 HSPF, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservation Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048.

⁴⁹² ENERGY STAR version 6.2, effective January 1, 2023.

⁴⁹³ As modeled in 'ASHP Partial Displacement Analysis 20240523.xlsx'

account for degradation over time. ⁴⁹⁴ If not available, use:

Existing Heating System	HSPF _{exist}	HSPF2 _{exist}
Air Source Heat Pump	5.44 ⁴⁹⁵	4.62
Electric Resistance or Electric Furnace	3.41 ⁴⁹⁶	3.41

DeratingHeat_{eff} = Efficient ASHP Heating derating

= 0% if Quality Installation is performed

= 11.8% if Quality Installation is not performed or unknown whether it was performed (e.g. midstream program) ⁴⁹⁷

DeratingHeat_{base} = Baseline ASHP Heating derating

= 11.8%

⁴⁹⁴ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

⁴⁹⁵ 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.

⁴⁹⁶ Electric resistance has a COP of 1.0, which equals 1/0.293 = 3.41 HSPF.

⁴⁹⁷ 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 3 ton, 16 SEER2, 13 EER2, 9 HSPF2 Air Source Heat Pump in a full displacement scenario installed with quality installation in an existing single family home in unknown location:

$$\begin{aligned}\Delta kWh &= ((861 * 36,000 * (1/(14.3 * (1-10.5\%)) - 1/(16 * (1-0\%)))) / 1,000) + ((2,254 * 1 * 36,000 * \\ &(1/(8.8 * (1-11.8\%)) - 1/(9 * 1 * (1-0\%)))) / 1,000) \\ &= 1,923 \text{ kWh}\end{aligned}$$

For example, for a three ton, 16 SEER2, 13 EER2, 9 HSPF2 Air Source Heat Pump installed without quality installation in an existing single family home in unknown location:

$$\begin{aligned}\Delta kWh &= ((861 * 36,000 * (1/(14.3 * (1-10.5\%)) - 1/(16 * (1-10.5\%)))) / 1,000) + ((2,254 * 1 * 36,000 * \\ &(1/(8.8 * (1-11.8\%)) - 1/(9 * 1 * (1-11.8\%)))) / 1,000) \\ &= 490 \text{ kWh}\end{aligned}$$

Early Replacement:

For example, for a 3 ton, 16 SEER2, 13 EER2, 9 HSPF2 Air Source Heat Pump that replaces an existing working Air Source Heat Pump in a full displacement scenario using quality installation with unknown efficiency ratings in unknown location:

$$\begin{aligned}\Delta kWh \text{ for remaining life of existing unit (1st 6 years):} \\ &= ((861 * 36,000 * (1/(8.7 * (1-10.5\%)) - 1/(16 * (1-0\%)))) / 1,000) + ((2,254 * 1 * 36,000 * \\ &(1/(4.62 * (1-11.8\%)) - 1/(9 * 1 * (1-0\%)))) / 1,000) \\ &= 12,941 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\Delta kWh \text{ for remaining measure life (next 12 years):} \\ &= ((861 * 36,000 * (1/(14.3 * (1-10.5\%)) - 1/(16 * (1-0\%)))) / 1,000) + ((2,254 * 1 * 36,000 * \\ &(1/(8.8 * (1-11.8\%)) - 1/(9 * 1 * (1-0\%)))) / 1,000) \\ &= 1,923 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] * CF$$

Early replacement:⁴⁹⁸

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

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER2_{exist} * (1 - DeratingCool_{base}))} - \frac{1}{(EER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] * CF$$

⁴⁹⁸ 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).

ΔkW for remaining measure life (next 12 years):

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] * CF$$

Where:

$EER2_{base}$ = Energy Efficiency Ratio 2 (EER2) of baseline Air Source Heat Pump (kBtu/hr / kW)
= 8 EER2 (8.32 EER)⁴⁹⁹

$EER2_{ee}$ = Energy Efficiency Ratio 2 (EER2) of baseline Air Source Heat Pump (kBtu/hr / kW)
= Actual - If not provided, convert SEER2 to EER2 using this formula:⁵⁰⁰
= $(-0.02 * SEER2^2) + (1.12 * SEER2)$

Or if unknown assume 11 EER2 (11.4 EER)⁵⁰¹

$EER2_{exist}$ = Energy Efficiency Ratio 2 (EER2) of existing cooling system (kBtu/hr / kW)
= Use actual EER2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁵⁰² If EER2 unknown but SEER2 available, convert using the equation:

$$EER2_{base} = (-0.02 * SEER2_{base}^2) + (1.12 * SEER2)$$

If SEER2 rating unavailable, use:

Existing Cooling System	EER_exist ⁵⁰³	EER2_exist
Air Source Heat Pump	8.55	8.12
Central AC	8.15	7.74
Room AC	7.7	7.3
No central cooling ⁵⁰⁴	Set '1/EER_exist' = 0	Set '1/EER2_exist' = 0
For new space conditioning, assume baseline Air Source Heat Pump	8.32	8

$DeratingCool_{eff}$ = Efficient 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 or unknown whether it was performed

⁴⁹⁹ Based on the lowest available EER2 of non-qualifying units on the CAC database, as accessed on 03/20/2025.

⁵⁰⁰ 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.

⁵⁰¹ Based on the ENERGY STAR version 6.2 minimum EER2 requirement.

⁵⁰² Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁵⁰³ Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012).

⁵⁰⁴ 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.

(e.g. midstream program)⁵⁰⁵

DeratingCool_{base} = Baseline Central Air Conditioner Cooling derating

= 10.5%

CF = Summer system peak Coincidence Factor for cooling

= 72% for non-QI or unknown-QI (e.g. midstream program)⁵⁰⁶

= 80% for QI or right sized units⁵⁰⁷

Time of Sale:

For example, for a 3 ton, 16 SEER2, 13 EER2, 9 HSPF2 Air Source Heat Pump installed with quality installation in unknown location:

$$\begin{aligned}\Delta kW &= ((36,000 * (1/(8 * (1 - 10.5\%)) - 1/(13 * (1 - 0\%)))) / 1,000) * 80\% \\ &= 1.807 \text{ kW}\end{aligned}$$

For example, for a three ton, 15 SEER2, 12.5 EER2, 9 HSPF2 Air Source Heat Pump installed without quality installation in unknown location:

$$\begin{aligned}\Delta kW &= ((36,000 * (1/(8 * (1 - 10.5\%)) - 1/(13 * (1 - 10.5\%)))) / 1,000) * 72\% \\ &= 1.3924 \text{ kW}\end{aligned}$$

Early Replacement:

For example, for a 3 ton, 16 SEER2, 13 EER2, 9 HSPF2 Air Source Heat Pump that replaces an existing working Air Source Heat Pump with quality installation and with unknown efficiency ratings in unknown location:

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

$$\begin{aligned}&= ((36,000 * (1/(8.23 * (1 - 10.5\%)) - 1/(13 * (1 - 0\%)))) / 1,000) * 80\% \\ &= 1.6946 \text{ kW}\end{aligned}$$

ΔkW for remaining measure life (next 12 years):

$$\begin{aligned}&= ((36,000 * (1/(8 * (1 - 10.5\%)) - 1/(13 * (1 - 0\%)))) / 1,000) * 80\% \\ &= 1.807 \text{ kW}\end{aligned}$$

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

⁵⁰⁵ Based on Cadmus assumption in IPL TRM— results in a QI savings that is within a feasible range.

⁵⁰⁶ 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)'.

⁵⁰⁷ This higher CF accounts for the demand benefit from right sizing the equipment.

MEASURE CODE: RS-HVC-ASHP-V09-270101

SUNSET DATE: 1/1/2030

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 SEER2 ≤9.6 (≤10 SEER). “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: SEER2 ≤9.6 (≤10 SEER) 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 meets ENERGY STAR⁵⁰⁸ specifications v6.2, effective January 1, 2023. While this ENERGY STAR program was sunsetted in 2026, the specifications remain relevant based on a review of products available on the market.⁵⁰⁹ The specifications require central air conditioners to meet the following minimum efficiency requirements:⁵¹⁰

- Split system central air conditioners – 15.2 SEER2 and 12.0 EER2

⁵⁰⁸ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁵⁰⁹ A review of central air conditioning equipment currently listed on the California Energy Commission appliance database (accessed March, 2026) shows that anywhere between 65-80% of available equipment falls below the ENERGY STAR version 6.2 specification minimum requirements.

⁵¹⁰ ENERGY STAR Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment, v6.2, effective January 1, 2023, are in terms of an updated metric, depicted as SEER2 and EER2. The updated test method as well as the updated ENERGY STAR specifications mimic the updated federal appliance standards. An equivalent stringency of these new standards for split system air conditioners are 16 SEER and 13 EER and for single-package air conditioners are 16 SEER and EER 12, as detailed in: Consortium for Energy Efficiency (CEE) Residential HVAC Specifications, Estimated Appendix M1 Equivalents, January 15, 2021.

- Single package central air conditioners – 15.2 SEER2 and 11.5 EER2

The measure characterization recommends sourcing the efficiency specifications from the actually installed equipment.

DEFINITION OF BASELINE EQUIPMENT

New Federal Standards affecting central air conditioners became effective January 1, 2023. The new standards effective in 2023, require any residential central air conditioner manufactured in, or imported into, the United States to have a minimum efficiency rating meeting the following:⁵¹¹

- Split system air conditioners – 13.4 SEER2
- Single-package air conditioners – 13.4 SEER2

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 remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.⁵¹²

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected equipment measure life is assumed to be 18 years.⁵¹³ 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.⁵¹⁴

DEEMED MEASURE COST ⁵¹⁵

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed costs are provided below:⁵¹⁶

Capacity Range	Efficient Cost (\$/ton)	Baseline Cost (\$/ton)	Incremental Cost (\$/ton)
< 2 tons	$(\$2,008 + (\$100 * (\text{SEER2} - 15.2))) + \803	$(\$1,813 + \$803)$	$(\$195 + (\$100 * (\text{SEER2} - 15.2)))$
≥2 tons - < 3 tons	$(\$2,536 + (\$100 * (\text{SEER2} - 15.2))) + \803	$(\$2,290 + \$803)$	$(\$246 + (\$100 * (\text{SEER2} - 15.2)))$

⁵¹¹ The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system air conditioners are 14 SEER and for single-package air conditioners are 14 SEER, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservation Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048

⁵¹² Baseline SEER and EER should be updated when new minimum federal standards become effective.

⁵¹³ 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".

⁵¹⁴ Assumed to be one third of effective useful life.

⁵¹⁵ Measure costs will be updated when results of MidAmerican's HVAC incremental cost study are available.

⁵¹⁶ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Baseline and additive efficiency costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See "Res HVAC Cost Update 2026" for more details.

Capacity Range	Efficient Cost (\$/ton)	Baseline Cost (\$/ton)	Incremental Cost (\$/ton)
≥3 tons - < 4 tons	$(\$2,266 + (\$100 * (SEER2 - 15.2)) + \$803)$	$(\$2,046 + \$803)$	$(\$220 + (\$100 * (SEER2 - 15.2)))$
≥ 4 tons	$(\$2,857 + (\$100 * (SEER2 - 15.2)) + \$803)$	$(\$2,580 + \$803)$	$(\$277 + (\$100 * (SEER2 - 15.2)))$

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 defaults from the table above.

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is presented in the table below.⁵¹⁷ This cost should be discounted to present value using the utilities' discount rate.⁵¹⁸

Capacity Range	Deferred Baseline Cost (\$/ton)
< 2 tons	$(\$1,813 + \$803)$
≥2 tons - < 3 tons	$(\$2,290 + \$803)$
≥3 tons - < 4 tons	$(\$2,046 + \$803)$
≥ 4 tons	$(\$2,580 + \$803)$

Quality Installation: The additional design and installation work associated with quality installation has been estimated to add \$150 to the installed cost.⁵¹⁹

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:

⁵¹⁷ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Baseline costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See "Res HVAC Cost Update 2026" for more details.

⁵¹⁸ Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.

⁵¹⁹ Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers.

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Coolee} * \left(\frac{1}{(SEER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right]$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Coolee} * \left(\frac{1}{(IEER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(IEER_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right]$$

Early replacement:⁵²⁰

For units with cooling capacities less than 65 kBtu/hr:

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

$$\Delta kWh = \left[\frac{EFLH_{cool} * \left(Capacity_{Coolexist} * \frac{1}{(SEER2_{exist} * (1 - DeratingCool_{base}))} \right) - \left(Capacity_{Coolee} * \frac{1}{(SEER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right]$$

ΔkWh for remaining measure life (next 12 years):

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Coolee} * \left(\frac{1}{(SEER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(SEER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right]$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

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

$$\Delta kWh = \left[\frac{EFLH_{cool} * \left(Capacity_{Coolexist} * \frac{1}{(IEER_{exist} * (1 - DeratingCool_{base}))} \right) - \left(Capacity_{Coolee} * \frac{1}{(IEER_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right]$$

ΔkWh for remaining measure life (next 12 years):

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{Coolee} * \left(\frac{1}{(IEER_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(IEER_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right]$$

Where:

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

= Dependent on location and building type⁵²¹ If climate zone and building type is

⁵²⁰ 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).

⁵²¹ 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). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

unknown, assume 824 hours⁵²²:

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)	583	977	537	784	541	921
Zone 6 (Mason City)	291	489	268	392	271	461
Average/Unknown	514	861	472	690	477	811

Capacity_{Coolnew} = Cooling output capacity of new equipment in Btu/hr (note 1 ton = 12,000Btu/hr)
= Actual installed - If actual size unknown, assume 32,867 Btu/hr⁵²³

Capacity_{Coolexist} = Cooling output capacity of existing equipment in Btu/hr (note 1 ton = 12,000Btu/hr)
= Actual - If actual size unknown, assume same as new installed unit

SEER_{2base} = Seasonal Energy Efficiency Ratio 2 (SEER) of baseline unit (kBtu/kWh)
= 13.4 SEER2 (14 SEER)⁵²⁴

SEER_{2exist} = Seasonal Energy Efficiency Ratio 2 (SEER2) of existing unit (kBtu/kWh)
= Use actual SEER2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ⁵²⁵ If unknown, assume:

Existing Cooling System	SEER _{exist} ⁵²⁶	SEER _{2exist}
Air Source Heat Pump	9.12	8.66
Central AC	8.60	8.2

SEER_{2ee} = Seasonal Energy Efficiency Ratio 2 (SEER2) of efficient unit (kBtu/kWh)
= Actual installed or 15.2SEER2 (16.0 SEER) if unknown⁵²⁷

⁵²² Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022.

⁵²³ Based on review of all available models on AHRI directory on 04/01/2022. See 'AHRI_20220401_USAC.xlsx' for more detail.

⁵²⁴ The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system air conditioners are 14 SEER and for single-package air conditioners are 14 SEER, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservation Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048

⁵²⁵ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁵²⁶ 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.

⁵²⁷ ENERGY STAR Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment, v6.1, effective January 1, 2023, are in terms of an updated metric, depicted as SEER2 and EER2. The updated test method as well as the updated ENERGY STAR specifications mimic the updated federal appliance standards. An equivalent stringency of these new standards for split system air conditioners are 16 SEER and 13 EER and for single-package air conditioners are 16 SEER and EER 12, as detailed in: Consortium for Energy Efficiency (CEE) Residential HVAC Specifications, Estimated Appendix M1 Equivalents, January 15, 2021.

DeratingCool _{eff}	= Efficient Central Air Conditioner Cooling derating = 0% if Quality Installation is performed = 10.5% if Quality Installation is not performed or unknown (e.g. mid or upstream program) ⁵²⁸
DeratingCool _{base}	= Baseline Central Air Conditioner Cooling derating = 10.5%
IEER _{base}	= Integrated Energy Efficiency Ratio (IEER) of baseline unit (kBtu/kWh) = 11.4 ⁵²⁹
IEER _{exist}	= Integrated Energy Efficiency Ratio (IEER) of existing unit (kBtu/kWh) = Use actual IEER rating where it is possible to measure, or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ⁵³⁰
IEER _{ee}	= Integrated Energy Efficiency Ratio (IEER) of efficient unit (kBtu/kWh) = Actual installed

Time of Sale:

For example, for a 3 ton unit with SEER2 rating of 15.2, in unknown location with quality installation:

$$\Delta \text{kWh} = (824 * 36,000 * (1/(13.4 * (1-10.5\%)) - 1/(15.2 * (1-0\%)))) / 1,000$$

$$= 521.9 \text{ kWh}$$

For example, for a 3 ton unit with SEER2 rating of 15.2, in unknown location without quality installation:

$$\Delta \text{kWh} = (824 * 36,000 * (1/(13.4 * (1-10.5\%)) - 1/(15.2 * (1-10.5\%)))) / 1,000$$

$$= 292.9 \text{ kWh}$$

Early Replacement:

For example, for a 3 ton unit, with SEER2 rating of 15.2 replacing an existing unit with quality installation with unknown efficiency in a single family home in Burlington, IA:

$$\Delta \text{kWh}(\text{for first 6 years}) = (977 * 36,000 * (1/(9.6 * (1-10.5\%)) - 1/(15.2 * (1-0\%)))) / 1,000$$

$$= 1,779.6 \text{ kWh}$$

$$\Delta \text{kWh}(\text{for next 12 years}) = (977 * 36,000 * (1/(13.4 * (1-10.5\%)) - 1/(15.2 * (1-0\%)))) / 1,000$$

$$= 618.8 \text{ kWh}$$

Therefore, record a savings adjustment of 35% (618.8/1,779.6) after 6 years.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

⁵²⁸ Based on Cadmus assumption in IPL TRM— results in a QI savings that is within a feasible range.

⁵²⁹ Based on IECC 2012 requirements.

⁵³⁰ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

$$\Delta kW = \left[\frac{Capacity_{Coolee} * \left(\frac{1}{(EER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] * CF$$

Early replacement:⁵³¹

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

$$\Delta kW = \left[\frac{\left(Capacity_{Coolexist} * \frac{1}{(EER2_{exist} * (1 - DeratingCool_{base}))} \right) - \left(Capacity_{Coolee} * \frac{1}{(EER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] * CF$$

ΔkW for remaining measure life (next 12 years):

$$\Delta kW = \left[\frac{Capacity_{Coolee} * \left(\frac{1}{(EER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER2_{ee} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] * CF$$

Where:

$EER2_{base}$ = Energy Efficiency Ratio 2 (EER2) of baseline unit⁵³²

= 9 EER2 (9.36 EER)

$EER2_{exist}$ = Energy Efficiency Ratio 2 (EER2) of existing unit

= Actual EER2 of unit should be used. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁵³³ If EER2 is unknown, use 8.9⁵³⁴

$EER2_{ee}$ = Energy Efficiency Ratio 2 (EER2) of efficient unit

= Actual installed - Or if unknown 12 EER2 (12.5 EER)⁵³⁵

$DeratingCool_{eff}$ = Efficient 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 or unknown (e.g. mid or upstream program)⁵³⁶

⁵³¹ 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).

⁵³² Based on the lowest EER2 of products listed on the California Appliance Database, accessed April 2025.

⁵³³ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁵³⁴ Based on SEER2 of 9.6, using formula above to give 8.9 EER.

⁵³⁵ ENERGY STAR version 6.2, effective January 1, 2023.

⁵³⁶ Based on Cadmus assumption in IPL TRM— results in a QI savings that is within a feasible range.

DeratingCool_{base} = Baseline Central Air Conditioner Cooling derating

= 10.5%

CF = Summer system peak Coincidence Factor for cooling

= 68% for non-QI or unknown (e.g. mid or upstream program) ⁵³⁷

= 80% for QI or right sized units ⁵³⁸

Time of Sale:

For example, for a 3 ton unit with EER2 rating of 13 installed with quality installation/right sized in unknown location:

$$\Delta kW = (36,000 * (1/(9 * (1 - 10.5\%)) - 1/(13 * (1 - 0\%)))) / 1,000 * 0.80$$

$$= 1.36 \text{ kW}$$

For example, for a 3 ton unit with EER rating of 12.5 installed without quality installation in unknown location:

$$\Delta kW = (36,000 * (1/(9 * (1 - 10.5\%)) - 1/(13 * (1 - 10.5\%)))) / 1,000 * 0.68$$

$$= 0.9351 \text{ kW}$$

Early Replacement:

For example, for a 3 ton unit, with EER rating of 13 replacing an existing unit with unknown efficiency in a single family home in Burlington, IA with quality installation:

$$\Delta kW \text{ (for first 6 years)} = (36,000 * (1/(8.9 * (1 - 10.5\%)) - 1/(13 * (1 - 0\%)))) / 1,000 * 0.80$$

$$= 1.4002 \text{ kW}$$

$$\Delta kW \text{ (for next 12 years)} = (36,000 * (1/(9 * (1 - 10.5\%)) - 1/(13 * (1 - 0\%)))) / 1,000 * 0.80$$

$$= 1.36 \text{ kW}$$

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-V09-270101

SUNSET DATE: 1/1/2030

⁵³⁷ 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.

⁵³⁸ 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 $\leq 75\%$. “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 $\leq 75\%$ and cost of any repairs <\$811.

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/hr) 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/hr), gas-fired, standard-efficiency water boiler. The current Federal Standard minimum AFUE rating is 84%.⁵³⁹

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.⁵⁴⁰

Early replacement: Remaining life of existing equipment is assumed to be 8 years.⁵⁴¹

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is provided below, dependent on efficiency:⁵⁴²

⁵³⁹ Code of Federal Regulations for gas-fired hot water boilers manufactured on or after January 15, 2021 (10 CFR 432(e)(3))

⁵⁴⁰ Federal Appliance Standards, Chapter 8.3 of DOE Technical Support Documents, Table 8.3.3.

⁵⁴¹ Assumed to be one third of effective useful life.

⁵⁴² 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
84%	\$4,053	N/A
85%	\$4,468	\$415
86%	\$5,264	\$1,211
87%	\$5,328*	\$1,275
88%	\$5,392*	\$1,339
89%	\$5,455*	\$1,402
90%	\$5,519*	\$1,466
91%	\$5,583	\$1,530
92%	\$5,734*	\$1,681
93%	\$5,885*	\$1,832
94%	\$6,036*	\$1,983
95%	\$6,188*	\$2,135
96%	\$6,339*	\$2,286
97%	\$6,490*	\$2,437
98%	\$6,641*	\$2,588
99%	\$6,792	\$2,739

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 \$4,053. This cost should be discounted to present value using the utilities' discount rate.⁵⁴³

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 marked with an *. See "Boiler_DOE Chapter 8.xls" for more information.

⁵⁴³ 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:⁵⁴⁴

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:⁵⁴⁵

Climate Zone (City Based Upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	754	869	526	738	641	890
Zone 6 (Mason City)	1,084	1,246	755	1,059	921	1,277
Average/Unknown	854	983	596	835	726	1,007

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 using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁵⁴⁶ If unknown, assume 61.6 AFUE%⁵⁴⁷

AFUE_{base} = Baseline boiler Annual Fuel Utilization Efficiency (AFUE) rating

⁵⁴⁴ 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).

⁵⁴⁵ 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 unit’s 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). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁵⁴⁶ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁵⁴⁷ 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.

	= 84%
AFUE _{eff}	= Efficient boiler Annual Fuel Utilization Efficiency (AFUE) rating
	= Actual
Derating _{Eff}	= Derating of AFUE to account for units not operating in field at rated efficiency
	= 5.9% ⁵⁴⁸
Derating _{Base}	= Derating of AFUE to account for units not operating in field at rated efficiency
	= 3.3% ⁵⁴⁹

Time of Sale:

For example, for a 100,000 Btuh 92% AFUE boiler purchased and installed for existing home in unknown location:

$$\Delta \text{Therms} = (983 * 100,000 * ((0.92 * (1-0.059))/(0.84 * (1-0.033)) - 1))/100,000$$

$$= 64.7 \text{ Therms}$$

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 unknown location:

Δ Therms for remaining life of existing unit (first 8 years):

$$= (983 * 100,000 * ((0.88 * (1-0.059))/(0.616 * (1-0.033)) - 1))/100,000$$

$$= 383.5 \text{ Therms}$$

Δ Therms for remaining measure life (next 17 years):

$$= (983 * 100,000 * ((0.88 * (1-0.059))/(0.84 * (1-0.033)) - 1))/100,000$$

$$= 19.1 \text{ Therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * \text{GCF}$$

Where:

Δ Therms	= Therm impact calculated above
GCF	= Gas Coincidence Factor for heating ⁵⁵⁰
	= 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 unknown location:

$$\Delta \text{Therms} = 19.1 * 0.014378$$

$$= 0.2746 \text{ Therms}$$

⁵⁴⁸ Based on findings from Massachusetts study; Cadmus “High Efficiency Heating Equipment Impact Evaluation,” March 2015.

⁵⁴⁹ Ibid.

⁵⁵⁰ 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-HVC-GHEB-V06-250101

SUNSET DATE: 1/1/2028

2.4.4 Furnace

DESCRIPTION

This measure covers the installation of a residential sized (<225,000 Btuh/hr) 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/hr) 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/hr) 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 $\leq 75\%$. “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 $\leq 75\%$ 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%.⁵⁵¹ It is assumed that ‘Quality Installation’ did not occur.

Early Replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed

⁵⁵¹ 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.

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.⁵⁵² 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.⁵⁵³

DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below.⁵⁵⁴

AFUE	Installed Cost	Incremental Installed Cost
Baseline	(\$1,421 + \$2,930)	N/A
≤ 95%	(\$1,598 + \$2,930)	\$177
> 95% - < 97%	(\$2,684 + \$2,930)	\$1,190
≥ 97%	(\$6,928 + \$2,930)	\$5,096

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 85% AFUE baseline unit is assumed to be (\$1,421 + \$2,930).⁵⁵⁵ This cost should be discounted to present value using the utilities' discount rate.⁵⁵⁶

Quality Installation: The additional design and installation work associated with quality installation has been estimated to add \$90 to the installed cost.⁵⁵⁷

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RG04 – Residential Other Heating

⁵⁵² Federal Appliance Standards, Chapter 8.3 of DOE Technical Support Documents, Table 8.3.3.

⁵⁵³ Assumed to be one third of effective useful life

⁵⁵⁴ Furnace costs based upon MidAmerican program data from the 2024 and 2025 program years. Baseline and labor costs are interpolated from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs are presented after baseline costs so that they may be easily distinguished as needed. See "Res HVAC Cost Update 2026" for more details.

⁵⁵⁵ Ibid

⁵⁵⁶ Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.

⁵⁵⁷ Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers. As of April 2021, there are no plans to update this data, per MidAmerican.

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:

$$\Delta \text{Therms} = \frac{\frac{\text{EFLH} * \text{Capacity}}{(1 - \text{Derating}_{\text{eff}})} * \left(\frac{\text{AFUE}_{\text{eff}} * (1 - \text{Derating}_{\text{eff}})}{\text{AFUE}_{\text{base}} * (1 - \text{Derating}_{\text{base}})} - 1 \right)}{100,000} * (1 - \text{HeatLoadFactor})$$

Early replacement:⁵⁵⁸

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

$$= \frac{\frac{\text{EFLH} * \text{Capacity}}{(1 - \text{Derating}_{\text{eff}})} * \left(\frac{\text{AFUE}_{\text{eff}} * (1 - \text{Derating}_{\text{eff}})}{\text{AFUE}_{\text{exist}} * (1 - \text{Derating}_{\text{base}})} - 1 \right)}{100,000} * (1 - \text{HeatLoadFactor})$$

Δ Therms for remaining measure life (next 14 years):

$$= \frac{\frac{\text{EFLH} * \text{Capacity}}{(1 - \text{Derating}_{\text{eff}})} * \left(\frac{\text{AFUE}_{\text{eff}} * (1 - \text{Derating}_{\text{eff}})}{\text{AFUE}_{\text{base}} * (1 - \text{Derating}_{\text{base}})} - 1 \right)}{100,000} * (1 - \text{HeatLoadFactor})$$

Where:

EFLH = Equivalent Full Load Hours for heating

= Dependent on location. and building type.⁵⁵⁹ If climate zone and building type is unknown, assume 965 hours⁵⁶⁰:

Climate Zone (City Based Upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	754	869	526	738	641	890

⁵⁵⁸ 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).

⁵⁵⁹ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details. *As of April 2021, there are no plans to update this data & report, per MidAmerican.*

⁵⁶⁰ Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022.

Climate Zone (City Based Upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 6 (Mason City)	1,084	1,246	755	1,059	921	1,277
Average/Unknown	854	983	596	835	726	1,007

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 using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁵⁶¹ If unknown, assume 64.4 AFUE%⁵⁶²

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} = Efficient furnace Annual Fuel Utilization Efficiency (AFUE) rating
= Actual

Derating_{eff} = Efficient furnace AFUE derating
= 0% if Quality Installation is performed
= 6.4% if Quality Installation is not performed or unknown (e.g mid or upstream program)⁵⁶³

Derating_{base} = Baseline furnace AFUE derating
= 6.4%⁵⁶⁴ HeatLoadFactor = Portion of HeatLoad displaced by ASHP in partial displacement applications where a new furnace is installed together with a new ASHP. Varies by Switchover Temperature and Climate Region. If Switchover Temperature is unknown, use 26F.⁵⁶⁵
= 0.0 if no heat pump is present on-site
= 1.0 If cold climate heat pump is present on-site
= 1.0 if full displacement by the heat pump or if Switchover Temperature is lower than 17°F

⁵⁶¹ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁵⁶² Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012).

⁵⁶³ 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.

⁵⁶⁴ As above.

⁵⁶⁵ As modeled in 'ASHP Partial Displacement Analysis 20240523.xlsx'

Climate Zone (City Based Upon)	HeatLoadFactor (by Switchover Temperature)										
	47°F	44°F	41°F	38°F	35°F	32°F	29°F	26°F	23°F	20°F	17°F
Zone 5 (Burlington)	8%	14%	20%	26%	39%	52%	59%	71%	79%	82%	89%
Zone 6 (Mason City)	6%	11%	15%	19%	25%	33%	35%	43%	49%	54%	61%
Average/Unknown	7%	12%	17%	22%	34%	46%	50%	59%	66%	71%	78%

Time of Sale:

For example, for an 80,000 Btuh 95% AFUE furnace purchased and installed with quality installation for an existing single family home in unknown location:

$$\begin{aligned}\Delta\text{Therms} &= ((983 * 80,000)/(1 - 0\%) * (((0.95 * (1 - 0\%)) / (0.85 * (1 - 6.4\%))) - 1)/100,000 * \\ &\quad (1-0)) \\ &= 152.6 \text{ Therms}\end{aligned}$$

For example, for an 80,000 Btuh 95% AFUE furnace purchased and installed without quality installation for an existing single family home in unknown location:

$$\begin{aligned}\Delta\text{Therms} &= ((983 * 80,000)/(1 - 6.4\%) * (((0.95 * (1 - 6.4\%)) / (0.85 * (1 - 6.4\%))) - 1)/100,000 \\ &\quad * (1-0)) \\ &= 98.8 \text{ Therms}\end{aligned}$$

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 an existing single family home in unknown location:

$$\begin{aligned}\Delta\text{Therms for remaining life of existing unit (first 6 years):} \\ &= ((983 * 80,000)/(1 - 0\%) * (((0.95 * (1 - 0\%)) / (0.644 * (1 - 6.4\%))) - 1)/100,000 * (1-0)) \\ &= 453.0 \text{ Therms}\end{aligned}$$

$$\begin{aligned}\Delta\text{Therms for remaining measure life (next 14 years):} \\ &= ((983 * 80,000)/(1 - 0\%) * (((0.95 * (1 - 0\%)) / (0.85 * (1 - 6.4\%))) - 1)/100,000 * (1-0)) \\ &= 152.6 \text{ Therms}\end{aligned}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for heating⁵⁶⁶
= 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 single family home in unknown location:

$$\begin{aligned}\Delta\text{Therms} &= 152.6 * 0.016525 \\ &= 2.52 \text{ Therms}\end{aligned}$$

⁵⁶⁶ 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-HVC-FRNC-V07-250101

SUNSET DATE: 1/1/2028

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 years⁵⁶⁷.

DEEMED MEASURE COST

The capital cost for this measure is assumed to be \$97⁵⁶⁸ 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

⁵⁶⁷ Consistent with assumed life of a new gas furnace. Federal Appliance Standards, Chapter 8.3 of DOE Technical Support Documents, Table 8.3.3.

⁵⁶⁸ 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

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

Where:

$$\text{Heating Savings} = \text{Blower motor savings during heating season}^{569}$$

Building Type	Vintage	End Use	Heating Savings (kWh)		
			Zone 5 (Burlington)	Zone 6 (Mason City)	Average/Unknown
Manufactured	Existing	Heat Central Furnace	268.4	381.5	301.6
Manufactured	New	Heat Central Furnace	193.5	275.0	217.4
Multifamily	Existing	Heat Central Furnace	222.6	316.4	250.1
Multifamily	New	Heat Central Furnace	158.8	225.7	178.5
Single-family	Existing	Heat Central Furnace	262.0	372.4	294.4
Single-family	New	Heat Central Furnace	227.7	323.7	255.9
Residential ⁵⁷⁰	Residential	Heat Central Furnace	290.0		

$$\text{Cooling Savings} = \text{Blower motor savings during cooling season}$$

If home has Central AC:

Building Type	Vintage	End Use	Cooling Savings with CAC (kWh)		
			Zone 5 (Burlington)	Zone 6 (Mason City)	Average/Unknown
Manufactured	Existing	Cool Central	266.2	208.0	252.3
Manufactured	New	Cool Central	217.3	183.1	209.2
Multifamily	Existing	Cool Central	248.5	199.0	236.7
Multifamily	New	Cool Central	216.7	182.8	208.6
Single-family	Existing	Cool Central	273.5	211.7	258.8
Single-family	New	Cool Central	222.7	185.9	214.0
Residential	Residential	Cool Central	256.5		

$$\text{If No Central AC} = 147.6 \text{ kWh}^{571}$$

If unknown⁵⁷²:

⁵⁶⁹ 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.

⁵⁷⁰ Where location and home type is unknown.

⁵⁷¹ These savings are for those homes that use the fan on continuous mode (13% of households) from Focus on Energy study.

⁵⁷² 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.

Building Type	Vintage	End Use	Cooling Savings, If Cooling Unknown (kWh)		
			Zone 5 (Burlington)	Zone 6 (Mason City)	Average/Unknown
Manufactured	Existing	Cool Central	249.4	199.5	237.6
Manufactured	New	Cool Central	207.4	178.1	200.5
Multifamily	Existing	Cool Central	234.2	191.7	224.1
Multifamily	New	Cool Central	206.9	177.8	200.0
Single-family	Existing	Cool Central	255.7	202.7	243.1
Single-family	New	Cool Central	212.1	180.5	204.6
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:

Building Type	Vintage	Total Savings (kWh)								
		With CAC			No CAC			Unknown CAC		
		Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ Unknown	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ Unknown	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ Unknown
Manufactured	Existing	558.9	613.8	578.2	440.3	553.4	473.5	542.1	605.3	563.5
Manufactured	New	435.1	482.5	450.9	365.4	447.0	389.3	425.3	477.4	442.2
Multifamily	Existing	495.4	539.7	511.1	394.5	488.3	422.0	481.2	532.5	498.6
Multifamily	New	399.8	432.9	411.4	330.7	397.7	350.4	390.0	427.9	402.8
Single-family	Existing	559.8	608.4	577.5	433.9	544.3	466.3	542.0	599.4	561.8
Single-family	New	474.8	533.9	494.2	399.6	495.6	427.8	464.2	528.5	484.8
Residential		570.8			462.0			555.5		

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\frac{\text{NoACCooling Savings}}{\text{Cooling Season Hours}} + \frac{\text{Cooling Savings} - \text{NoACCooling Savings}}{FLH_{cooling}} \right) * CF$$

Where:

NoACCooling Savings = kWh savings in cooling season for homes without cooling
= 147.6 kWh

Cooling Season Hours = Total hours during cooling season
= 2,952⁵⁷³

Cooling Savings = kWh savings in cooling season for homes with cooling
= See tables above

FLH_{cooling} = Full load hours of air conditioning
= Dependent on location⁵⁷⁴:

⁵⁷³ Based on 123 days where CDD 65>0, multiplied by 24.

⁵⁷⁴ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC

Building Type	Vintage	Cooling Load Hours—EFLHc		
		Zone 5 (Burlington)	Zone 6 (Mason City)	Average / Unknown
Manufactured	Existing	921	461	811
Manufactured	New	541	271	477
Multifamily	Existing	784	392	690
Multifamily	New	537	268	472
Single-family	Existing	977	489	861
Single-family	New	583	291	514
Residential	Residential	794		

CF = Summer System Peak Coincidence Factor for Cooling
= 68%⁵⁷⁵

Using default values above the total savings are provided below:

Building Type	Vintage	Total Savings (kW)		
		With CAC	No CAC	Unknown CAC
All	All	0.1272	0.0465	0.1141

NATURAL GAS SAVINGS

$$\Delta \text{Therms}^{576} = - \frac{\text{Heating Savings} * 0.03412}{\text{AFUE}}$$

Where:

0.03412 = Converts kWh to Therms
AFUE = Efficiency of the furnace
= Actual. If unknown assume 95%⁵⁷⁷

Using default values above the total savings are provided below:

Building Type	Vintage	Total Savings (Therms)		
		Zone 5 (Burlington)	Zone 6 (Mason City)	Average/Unknown
Manufactured	Existing	- 9.6	- 13.7	- 10.8
Manufactured	New	- 6.9	- 9.9	- 7.8
Multifamily	Existing	- 8.0	- 11.4	- 9.0
Multifamily	New	- 5.7	- 8.1	- 6.4
Single-family	Existing	- 9.4	- 13.4	- 10.6
Single-family	New	- 8.2	- 11.6	- 9.2
Residential	Residential	- 10.4		

data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁵⁷⁵ 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)'..

⁵⁷⁶ 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.

⁵⁷⁷ Minimum ENERGY STAR efficiency after 2/1/2012.

PEAK GAS SAVINGS

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

Where:

 $\Delta Therms$ = Therm impact calculated aboveGCF = Gas Coincidence Factor for heating⁵⁷⁸

= 0.016525 for Residential Space Heating (other)

Building Type	Vintage	Total Savings (Peak Therms)		
		Zone 5 (Burlington)	Zone 6 (Mason City)	Average/Unknown
Manufactured	Existing	-0.159	-0.226	-0.179
Manufactured	New	-0.115	-0.163	-0.129
Multifamily	Existing	-0.132	-0.188	-0.148
Multifamily	New	-0.094	-0.134	-0.106
Single-family	Existing	-0.155	-0.221	-0.175
Single-family	New	-0.135	-0.192	-0.152
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**

⁵⁷⁸ 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 STAR⁵⁷⁹ 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:

- a) 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.
- b) 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 below⁵⁸⁰:

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

⁵⁷⁹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁵⁸⁰ ENERGY STAR version 3.2, effective January 1, 2012.

Product Type	Cooling EER	Heating COP
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: 14.3 SEER2, 7.5 HSPF2, and 8 EER2.⁵⁸¹ 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:⁵⁸²

$$\text{For } \leq 55 \text{ gallons: EF} = 0.96 - (0.0003 * \text{rated volume in gallons})$$

$$\text{For } > 55 \text{ gallons: EF} = 2.057 - (0.00113 * \text{rated volume in gallons})$$

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: 14.3 SEER2, 7.5 HSPF2, and 8 EER2. 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:

$$\text{EF} = 0.93 - (0.00132 * \text{rated volume in gallons})^{583}$$

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:

$$\text{EF} = (0.67 - 0.0019 * \text{rated volume in gallons})^{584}$$

If size is unknown, assume 40 gallon; 0.594 EF

If DHW fuel is unknown, assume electric DHW provided above.

New Federal Standards affecting heat pumps became effective January 1, 2023. The new standards effective in 2023, require any residential heat pump manufactured in, or imported into, the United States to have a minimum efficiency rating meeting the following:⁵⁸⁵

- Split system heat pump – 14.3 SEER2 and 7.5 HSPF2 (15 SEER and 8.8 HSPF)
- Single-package heat pump – 13.4 SEER2 and 6.7 HSPF2 (14 SEER and 8 HSPF)

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

⁵⁸¹ Based on the lowest available EER2 of non-qualifying units on the CAC database, as accessed on 03/20/2025.

⁵⁸² Minimum Federal Standard as of 4/1/2015; Title 10 Chapter II Subchapter D Part 430 Subpart C 430.32.

⁵⁸³ Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497.

⁵⁸⁴ Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497.

⁵⁸⁵ The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and HSPF2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system heat pumps are 15 SEER and 8.8 HSPF and for single-package heat pumps are 14 SEER and 8 HSPF, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservation Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048.

life.

It is assumed that ‘Quality Installation’ did not occur.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for Time of Sale or New Construction is assumed to be 25 years.⁵⁸⁶

For early replacement, the remaining life of existing equipment is assumed to be 8 years.⁵⁸⁷

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, minus the assumed installation cost of the baseline equipment.

Default baseline costs are provided in the table below:

Baseline Equipment Type	Capacity Range	Baseline Cost (\$/ton) ⁵⁸⁸
Centrally Ducted Air Source Heat Pumps	< 2 tons	(\$4,627 + \$900)
	≥ 2 to < 3 tons	(\$3,526 + \$900)
	≥ 3 to < 4 tons	(\$2,509 + \$900)
	≥ 4 tons	(\$2,177 + \$900)
Geothermal Source Heat Pumps	< 2 tons	(\$7,107 + \$2,747)
	≥ 2 to < 3 tons	(\$5,081 + \$2,747)
	≥ 3 to < 4 tons	(\$3,268 + \$2,747)
	≥ 4 tons	(\$4,268 + \$2,747)

Default full cost of the efficient GSHP is provided in the table below:

Capacity Range	Full Install Cost (\$/ton) ⁵⁸⁹
< 2 tons	(\$7,313 + (\$1167 * (COP - 3.6)) + \$2,747)
≥ 2 to < 3 tons	(\$5,228 + (\$1167 * (COP - 3.6)) + \$2,747)
≥ 3 to < 4 tons	(\$3,363 + (\$1167 * (COP - 3.6)) + \$2,747)
≥ 4 tons	(\$4,391 + (\$1167 * (COP - 3.6)) + \$2,747)

Note if replacing an existing Geothermal Source Heat Pump with a functioning ground or water loop, it should be assumed that the indoor components of the Geothermal Source Heat Pump are consistent with the incremental cost

⁵⁸⁶ The expected system life of indoor components is assumed to be 25 years as per DOE estimate: See “Geothermal Heat Pumps _ Department of Energy”. The ground loop life is estimated at 50 years (based on U.S. DOE Office of Energy Efficiency & Renewable Energy, Energy Saver details and descriptions for Geothermal Heat Pumps).

⁵⁸⁷ Assumed to be one third of effective useful life

⁵⁸⁸ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Baseline costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See “Res HVAC Cost Update 2026” for more details.

⁵⁸⁹ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Additive efficiency costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See “Res HVAC Cost Update 2026” for more details.

of an efficient ASHP over the baseline ASHP. The incremental cost for this scenario only is provided below.

Capacity Range	Incremental Cost (\$/ton) ⁵⁹⁰
< 2 tons	(\$2,686 + (\$1167 * (COP - 3.6)))
≥ 2 to < 3 tons	(\$1,702 + (\$1167 * (COP - 3.6)))
≥ 3 to < 4 tons	(\$854 + (\$1167 * (COP - 3.6)))
≥ 4 tons	(\$2,214 + (\$1167 * (COP - 3.6)))

Early Replacement: The full installation cost of the Ground Source Heat Pump should be used (default provided above). Note if replacing an existing Geothermal Source Heat Pump with a functioning ground or water loop, the full cost will only reflect the install of the indoor components of the Geothermal Source Heat Pump. The full installation cost for this scenario only is provided below (note these costs are per ton of unit capacity).⁵⁹¹

Efficiency (SEER)	Efficiency (SEER2)	Full Retrofit Cost (Including Labor) per Ton of Capacity (\$/ton)
15.8	15	\$2,355 / ton + \$108
16	15.2	\$2,355 / ton + \$135
17	16.15	\$2,355 / ton + \$421
18+	17.1+	\$2,355 / ton + \$421

The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline Air Source Heat Pump is provided in the table below. This future cost should be discounted to present value using the nominal societal discount rate.⁵⁹²

Baseline Equipment Type	Capacity Range	Deferred Baseline Cost (\$/ton) ⁵⁹³
Centrally Ducted Air Source Heat Pumps	< 2 tons	(\$4,627 + \$900)
	≥ 2 to < 3 tons	(\$3,526 + \$900)
	≥ 3 to < 4 tons	(\$2,509 + \$900)
	≥ 4 tons	(\$2,177 + \$900)

Quality Installation: The additional design and installation work associated with quality installation has been

⁵⁹⁰ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Additive efficiency costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. See “Res HVAC Cost Update 2026” for more details.

⁵⁹¹ Costs based upon average cost per ton from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. Efficiency tiers have been converted to SEER2.

⁵⁹² Costs provided have not been adjusted for inflation and therefore should be discounted using a Real Discount Rate (RDR) rather than a nominal one.

⁵⁹³ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Baseline costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See “Res HVAC Cost Update 2026” for more details.

estimated to add \$150 to the installed cost.⁵⁹⁴

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RE12 – Residential Single Family Water Heat (Electric)

Loadshape RG07 – Residential Water Heat (Gas)

⁵⁹⁴ Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers, see 'Iowa HVAC Incremental Cost Study' for details.

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Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale, New Construction:

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings] + [DHW\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{(EER2_{Base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-PL} * (1 - DeratingCool_{eff}))} \right) + FLF_{Cool} * \left(\frac{1}{(EER2_{Base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-FL} * (1 - DeratingCool_{eff}))} \right) \right)}{1,000} \right] \\ + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{(HSPF2_{Base} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-PL} * 3.412 * (1 - DeratingHeat_{eff}))} \right) + FLF_{Heat} * \left(\frac{1}{(HSPF2_{Base} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-FL} * 3.412 * (1 - DeratingHeat_{eff}))} \right) \right)}{1,000} \right] \\ + \left[\frac{ElecDHW * \%DHWDisp * \frac{1}{EF_{ELEC}} * GPD * Household * 365 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0}{3,412} \right]$$

Early replacement:⁵⁹⁵

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

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings] + [DHW\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{(EER2_{Exist} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-PL} * (1 - DeratingCool_{eff}))} \right) + FLF_{Cool} * \left(\frac{1}{(EER2_{Exist} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-FL} * (1 - DeratingCool_{eff}))} \right) \right)}{1,000} \right] \\ + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{(HSPF2_{Exist} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-PL} * 3.412 * (1 - DeratingHeat_{eff}))} \right) + FLF_{Heat} * \left(\frac{1}{(HSPF2_{Exist} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-FL} * 3.412 * (1 - DeratingHeat_{eff}))} \right) \right)}{1,000} \right]$$

⁵⁹⁵ 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).

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$$+ \left[\frac{ElecDHW * \%DHWDISP * \frac{1}{EF_{ELEC}} * GPD * Household * 365 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0}{3,412} \right]$$

ΔkWh for remaining measure life (next 17 years):

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings] + [DHW\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{(EER2_{Base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-PL} * (1 - DeratingCool_{eff}))} \right) + FLF_{Cool} * \left(\frac{1}{(EER2_{Base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-FL} * (1 - DeratingCool_{eff}))} \right) \right)}{1,000} \right]$$

$$+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{(HSPF2_{Base} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-PL} * 3.412 * (1 - DeratingHeat_{eff}))} \right) + FLF_{Heat} * \left(\frac{1}{(HSPF2_{Base} * (1 - DeratingHeat_{base}))} - \frac{1}{(COP_{EE-FL} * 3.412 * (1 - DeratingHeat_{eff}))} \right) \right)}{1,000} \right]$$

$$+ \left[\frac{ElecDHW * \%DHWDISP * \frac{1}{EF_{ELEC}} * GPD * Household * 365 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0}{3,412} \right]$$

Where:

$EFLH_{Cool}$ = Equivalent Full Load Hours for cooling
 = Dependent on location and building type.⁵⁹⁶ If climate zone and building type is unknown, assume 824 hours.⁵⁹⁷

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)	583	977	537	784	541	921
Zone 6 (Mason City)	291	489	268	392	271	461
Average/Unknown	514	861	472	690	477	811

$Capacity_{Cool}$ = Cooling output capacity of Geothermal Source Heat Pump (Btu/hr)
 = Actual (1 ton = 12,000 Btu/hr)

PLF_{Cool} = Part load cooling mode operation
 = 0.85 if variable speed GSHP⁵⁹⁸
 = 0 if single/constant speed GSHP
 = 0.71 if unknown speed type⁵⁹⁹

FLF_{Cool} = Equivalent full load cooling mode operation factor
 = 0.15 if variable speed GSHP
 = 1 if single/constant speed GSHP
 = 0.29 if unknown speed type⁶⁰⁰

$EER2_{Base}$ = Energy Efficiency Ratio 2 (EER2) of new baseline ASHP unit
 = 8 EER2 (8.32 EER)⁶⁰¹

$EER2_{Exist}$ = Energy Efficiency Ratio of existing cooling unit
 = Use actual EER2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁶⁰² If EER2 unknown but SEER2 available convert using

⁵⁹⁶ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁵⁹⁷ Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022.

⁵⁹⁸ Based on Cadmus analysis of the relationship between part- and full-load capacities from building simulations of BE opt (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.

⁵⁹⁹ Distribution of GSHP speed type is sourced from IPL 2022 program participation data (83% of installed GSHPs were variable speed).

⁶⁰⁰ Distribution of GSHP speed type is sourced from IPL 2022 program participation data (83% of installed GSHPs were variable speed).

⁶⁰¹ Based on the lowest available EER2 of non-qualifying units on the CAC database, as accessed on 03/20/2025.

⁶⁰² Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

the equation:

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

If SEER2 rating unavailable use:

Existing Cooling System	EER _{Exist} ⁶⁰³	EER2 _{exist}
Air Source Heat Pump	8.55	8.12
Central AC	8.15	7.74
Room AC	7.7	7.3
No central cooling ⁶⁰⁴	Set '1/EER _{exist} ' = 0	Set '1/EER2 _{exist} ' = 0
For new space heating, assume baseline Geothermal Source Heat Pump	8.32	8

EER_{EE - PL} = Part load Energy Efficiency Ratio (EER) of GSHP unit

= Actual installed with adjustment for pumping energy:⁶⁰⁵

$$\text{Adjusted EER (closed loop)} = 0.0000315 * EER^3 - 0.0111 * EER^2 + 0.959 * EER$$

$$\text{Adjusted EER (open loop)} = 0.00005 * EER^3 - 0.0145 * EER^2 + 0.93 * EER$$

EER_{EE - FL} = Full load Energy Efficiency Ratio (EER) of GSHP unit

= Actual installed with adjustment for pumping energy described above

DeratingCool_{eff} = Efficient GSHP cooling derating

= 0% if Quality Installation is performed

= 10.5% if Quality Installation is not performed or unknown whether it was performed (e.g. midstream program)⁶⁰⁶

Derating_{base} = Baseline GSHP cooling derating

= 10.5%

EFLH_{Heat} = Equivalent Full Load Hours for heating

= Dependent on location and building type.⁶⁰⁷ If climate zone and building type is unknown, assume 2,229 hours.⁶⁰⁸

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)	1,892	1,991	1,367	1,618	1,769	2,104
Zone 6 (Mason City)	2,717	2,858	1,964	2,322	2,540	3,020
Average/Unknown	2,143	2,254	1,549	1,832	2,003	2,382

⁶⁰³ Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012).

⁶⁰⁴ 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.

⁶⁰⁵ The methodology provided is based upon REMRate protocol 'Auxiliary Electric Energy of Ground Source Heat Pumps.'

⁶⁰⁶ Based on Cadmus assumption in IPL TRM— results in a QI savings that is within a feasible range.

⁶⁰⁷ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁶⁰⁸ Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022.

Capacity _{Heat}	= Full load heating output capacity of Geothermal Source Heat Pump (Btu/hr) = Actual (1 ton = 12,000 Btu/hr)
PLF _{Heat}	= Part load heating mode operation = 0.5 if variable speed GSHP ⁶⁰⁹ = 0 if single/constant speed GSHP = 0.42 if unknown speed type ⁶¹⁰
FLF _{Heat}	= Full load heating mode operation factor = 0.5 if variable speed GSHP = 1 if single/constant speed GSHP = 0.58 if unknown speed type ⁶¹¹
HSPF2 _{Base}	= Heating System Performance Factor 2 (HSPF2) of new replacement baseline heating system (kBtu/kWh) = 7.5 HSPF2 (8.8 HSPF) ⁶¹²
HSPF2 _{Exist}	= Heating System Performance Factor 2 (HSPF2) of existing heating system (kBtu/kWh) = Use actual HSPF2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ⁶¹³ If not available, use:

Existing Heating System	HSPF _{exist}	HSPF2 _{exist}
Air Source Heat Pump	5.44 ⁶¹⁴	4.62
Electric Resistance or Electric Furnace	3.41 ⁶¹⁵	3.41

COP _{EE - PL}	= Part load Coefficient of Performance of efficient unit = Actual Installed with adjustment for pumping energy: ⁶¹⁶ Adjusted COP (closed loop) = $0.000416 * COP^3 - 0.041 * COP^2 + 1.0086 * COP$
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⁶⁰⁹ 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.

⁶¹⁰ Distribution of GSHP speed type is sourced from IPL 2022 program participation data (83% of installed GSHPs were variable speed).

⁶¹¹ Distribution of GSHP speed type is sourced from IPL 2022 program participation data (83% of installed GSHPs were variable speed).

⁶¹² Minimum Federal Standard as of 1/1/2023.

⁶¹³ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

⁶¹⁴ 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.

⁶¹⁵ Electric resistance has a COP of 1.0, which equals $1/0.293 = 3.41$ HSPF.

⁶¹⁶ The methodology provided is based upon REMRate protocol 'Auxiliary Electric Energy of Ground Source Heat Pumps.'

	Adjusted COP (open loop)	$= 0.00067 * COP^3 - 0.0531 * COP^2 + 0.976 * COP$
$COP_{EE - FL}$	= Full load Coefficient of Performance of efficient unit	
	= Actual Installed with adjustment for pumping energy described above	
$DeratingHeat_{eff}$	= Efficient GSHP heating derating	
	= 0% if Quality Installation is performed	
	= 11.8% if Quality Installation is not performed or unknown whether it was performed (e.g. midstream program) ⁶¹⁷	
$DeratingHeat_{base}$	= 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	
	= 0.36 if unknown ⁶¹⁸	
$\%DHWDisp$	= Percentage of total DHW load that the GSHP will provide	
	= Actual if known	
	= If unknown and if desuperheater installed, assume 44% ⁶¹⁹	
	= if unknown and if unknown whether desuperheater is installed, assume 23% (e.g. midstream program application) ⁶²⁰	
	= 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 an Energy Factor. In version 3.0, these new ratings will be fully incorporated	
New Construction	= Actual; if unknown, assume federal standard: ⁶²¹	
	For ≤ 55 gallons:	$0.96 - (0.0003 * \text{rated volume in gallons})$
	For > 55 gallons:	$2.057 - (0.00113 * \text{rated volume in gallons})$
	If size is unknown, assume 50 gallon; 0.945 EF	
Existing Homes	= Actual - If unknown, assume pre 4/2015 Federal Standard: ⁶²²	
	$0.93 - (0.00132 * \text{rated volume in gallons})$	

⁶¹⁷ Based on Cadmus assumption in IPL TRM— results in a QI savings that is within a feasible range.

⁶¹⁸ NREL ResStock for the state of Iowa, based on the percentage of residential homes in the state that use electric water heating.

⁶¹⁹ Assumes that the desuperheater can provide two thirds of hot water needs for 8 months of the year ($2/3 * 2/3 = 44\%$). Based on input from Doug Dougherty, Geothermal Exchange Organization.

⁶²⁰ The 23% estimate is based on desuperheaters providing two thirds of hot water needs for eight months of the year (44%) multiplied by the estimate that desuperheaters will be installed in 51.5% of GSHP installations. Desuperheaters were installed in 51.5% of GSHP installations as sourced from IPL 2022 program participation data.

⁶²¹ Minimum Federal Standard as of 4/1/2015; Title 10 Chapter II Subchapter D Part 430 Subpart C 430.32

⁶²² Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497.

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 household⁶²³
= 17.6

Household = Average number of people per household

Household Unit Type	Household
Manufactured	1.96 ⁶²⁴
Single-Family – Deemed	2.55 ⁶²⁵
Multifamily – Deemed	1.71 ⁶²⁶
Unknown	2.52 ⁶²⁷
Custom	Actual Occupancy or Number of Bedrooms ⁶²⁸

365 = Days per year

γ_{Water} = Specific weight of water
= 8.33 pounds per gallon

T_{OUT} = Tank temperature
= 126.5°F⁶²⁹

T_{IN} = Incoming water temperature from well or municipal system
= 57.8⁶³⁰

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

3412 = Conversion from Btu to kWh

⁶²³ Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

⁶²⁴ Average household size by building type and water heater fuel type based on the 2007 RASS.

⁶²⁵ NREL ResStock building characteristic data released in 2022.

⁶²⁶ Ibid.

⁶²⁷ Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022.

⁶²⁸ 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.

⁶²⁹ CPUC Residential Retrofit - High Impact Measure Evaluation Report Draft. Dec. 7, 2009. Pg. 76. Average temperature setpoints for two utilities.

⁶³⁰ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. Water main temperature represents the average of TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state, used when location is unknown. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

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.:

$$\begin{aligned}\text{Adjusted Part Load EER} &= 0.0000315 * 20^3 - 0.0111 * 20^2 + 0.959 * 20 \\ &= 15.0\end{aligned}$$

$$\begin{aligned}\text{Adjusted Full Load EER} &= 0.0000315 * 18^3 - 0.0111 * 18^2 + 0.959 * 18 \\ &= 13.8\end{aligned}$$

$$\begin{aligned}\text{Adjusted Part Load COP} &= 0.000416 * 4.4^3 - 0.041 * 4.4^2 + 1.0086 * 4.4 \\ &= 3.7\end{aligned}$$

$$\begin{aligned}\text{Adjusted Full Load COP} &= 0.000416 * 3.4^3 - 0.041 * 3.4^2 + 1.0086 * 3.4 \\ &= 3.0\end{aligned}$$

$$\begin{aligned}\Delta \text{kWh} &= [(583 * 36,000 * ((0.85 * (1/(8 * (1-0.105))) - 1/(15 * (1-0)))) + (0.15 * (1/(8 * (1-0.105))) - 1/(13.8 * (1-0)))) / 1,000] + [(1,892 * 36,000 * ((0.5 * (1/(7.5 * (1-0.118))) - 1/(3.7 * 3.412 * (1-0)))) + (0.5 * (1/(7.5 * (1-0.118))) - 1/(3.0 * 3.412 * (1-0)))) / 1,000] + [(1 * 0.44 * 1/0.945 * 17.6 * 2.55 * 365 * 8.33 * (126.5-57.8) * 1)/3,412] \\ &= 1,513.8 + 4,152.5 + 1,279.3 \\ &= 6,945.6 \text{ kWh}\end{aligned}$$

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:

$$\begin{aligned}\Delta \text{kWh} &= [(583 * 36,000 * ((0.85 * (1/(8 * (1-0.105))) - 1/(15 * (1-0.105)))) + (0.15 * (1/(8 * (1-0.105))) - 1/(13.8 * (1-0.105)))) / 1,000] + [(1,892 * 36,000 * ((0.5 * (1/(7.5 * (1-0.118))) - 1/(3.7 * 3.412 * (1-0.118)))) + (0.5 * (1/(7.5 * (1-0.118))) - 1/(3.0 * 3.412 * (1-0.118)))) / 1,000] + [(1 * 0.44 * 1/0.945 * 17.6 * 2.55 * 365 * 8.33 * (126.5-57.8) * 1)/3,412] \\ &= 310.5 + 3,346.4 + 1,279.3 \\ &= 4,936.2 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale, New Construction:

$$\Delta kW = \left[\frac{\text{Capacity}_{Cool} * \left(\frac{1}{(\text{EER}_{2_{base}} * (1 - \text{DeratingCool}_{base}))} - \frac{1}{(\text{EER}_{EE-FL} * (1 - \text{DeratingCool}_{eff}))} \right)}{1,000} \right] * CF$$

Early replacement:

Δ kWh for remaining life of existing unit (first 8 years):

$$\Delta kW = \left[\frac{\text{Capacity}_{Cool} * \left(\frac{1}{(\text{EER}_{2_{Exist}} * (1 - \text{DeratingCool}_{base}))} - \frac{1}{(\text{EER}_{EE-FL} * (1 - \text{DeratingCool}_{eff}))} \right)}{1,000} \right] * CF$$

Δ kWh for remaining measure life (next 17 years):

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{(EER2_{base} * (1 - DeratingCool_{base}))} - \frac{1}{(EER_{EE-FL} * (1 - DeratingCool_{eff}))} \right)}{1,000} \right] * CF$$

Where:

EER2_{base} = Energy Efficiency Ratio 2 (EER2) of new baseline unit

= 8 EER2 (8.32 EER2)⁶³¹

EER2_{Exist} = Energy Efficiency Ratio 2 of existing cooling unit

= Use actual EER2 rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁶³² If EER2 unknown but SEER2 available convert using the equation:

$$EER2_{exist} = (-0.02 * SEER2_{exist}^2) + (1.12 * SEER2_{exist})$$

If SEER2 rating unavailable use:

Existing Cooling System	EER _{Exist} ⁶³³	EER2 _{Exist}
Air Source Heat Pump	8.55	8.12
Central AC	8.15	7.74
Room AC	7.7	7.3
No central cooling ⁶³⁴	Set '1/EER _{exist} ' = 0	Set '1/EER2 _{exist} ' = 0
For new space heating, assume baseline Geothermal Source Heat Pump	8.32	8

EER2_{FL} = Full load Energy Efficiency Ratio (EER) of ENERGY STAR GSHP unit

= Actual with adjustment for pumping energy described above

DeratingCool_{eff} = Efficient 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 or unknown whether it was performed (e.g. midstream program)⁶³⁵

DeratingCool_{base} = Baseline Central Air Conditioner Cooling derating

= 10.5%

CF = Summer system peak Coincidence Factor for cooling

⁶³¹ Based on the lowest available EER2 of non-qualifying units on the CAC database, as accessed on 03/20/2025.

⁶³² Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁶³³ Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012).

⁶³⁴ 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.

⁶³⁵ Based on Cadmus assumption in IPL TRM— results in a QI savings that is within a feasible range.

= 72% for non-QI or unknown QI (e.g. midstream program)⁶³⁶

= 80% for QI or right sized units⁶³⁷

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:

$$\begin{aligned}\text{Adjusted Full Load EER} &= 0.0000315 * 18^3 - 0.0111 * 18^2 + 0.959 * 18 \\ &= 13.8\end{aligned}$$

$$\begin{aligned}\Delta \text{kW} &= ((36,000 * (1/(8 * (1-0.105))) - 1/(13.8 * (1-0))))/1,000 * 0.80 \\ &= 1.9354 \text{ kW}\end{aligned}$$

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:

$$\begin{aligned}\Delta \text{kW} &= ((36,000 * (1/(8 * (1-0.105))) - 1/(13.8 * (1-0.105))))/1,000 * 0.72 \\ &= 1.5215 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

DHW savings for homes with existing gas hot water:

$$\begin{aligned}\Delta \text{Therms} &= [\text{DHW Savings}] \\ &= \frac{(1 - \text{ElecDHW}) * \% \text{DHWD} * \frac{1}{\text{EF}_{\text{Gas}}} * \text{GPD} * \text{Household} * 365 * \gamma \text{Water} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0}{100,000}\end{aligned}$$

Where:

EF_{GAS} = Energy Factor (efficiency) of gas water heater

New Construction = Actual – If unknown, assume federal standard:⁶³⁸

For ≤55 gallons: $0.675 - (0.0015 * \text{tank_size})$

For > 55 gallons: $0.8012 - (0.00078 * \text{tank size})$

If tank size unknown assume 40 gallons; 0.615 EF

Existing Homes = Actual – If unknown, assume pre 4/2015 Federal Standard:⁶³⁹

$(0.67 - 0.0019 * \text{rated volume in gallons})$

If size is unknown, assume 40 gallon; 0.594 EF

All other variables provided above.

⁶³⁶ 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)'.

⁶³⁷ This higher CF accounts for the demand benefit from right sizing the equipment,

⁶³⁸ Minimum Federal Standard as of 4/1/2015.

⁶³⁹ Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497.

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:

$$\begin{aligned}\Delta\text{Therms} &= ((1-0) * 0.44 * 1/0.615 * 17.6 * 2.55 * 365 * 8.33 * (126.5-57.8) * 1) / 100,000 \\ &= 67.1 \text{ Therms}\end{aligned}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

$$\begin{aligned}\Delta\text{Therms} &= \text{Therm impact calculated above} \\ \text{GCF} &= \text{Gas Coincidence Factor for water heating} \\ &= 0.2952\% \text{ for Residential Water Heating}\end{aligned}$$

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:

$$\begin{aligned}\Delta\text{PeakTherms} &= 67.1 * 0.002952 \\ &= 0.1981 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GSHP-V10-270101

SUNSET DATE: 1/1/2030

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.⁶⁴⁰

It is not recommended to use this characterization for heat pumps systems that are mix-ducted, i.e. ductless air handlers are installed in combination with a centrally ducted evaporator. Please refer to 2.4.1 Central Air Source Heat Pump instead.

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

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.

The measure characterization recommends sourcing the efficiency specifications from the actually installed equipment. If those values are not known, the default equipment efficiency recommendations are based on ENERGY STAR⁶⁴¹ specifications v6.2, effective January 1, 2023. The specifications require heat pumps to meet the following minimum efficiency requirements:

- Split system heat pump – 15.2 SEER2 and 7.8 HSPF2
- Single-package heat pump – 15.2 SEER2 and 7.2 HSPF2
- Cold Climate heat pump – 15.2 SEER2 and 8.5 HSPF2

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, baseline equipment must be a permanent electric resistance heating

⁶⁴⁰ 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 2°F higher than any remaining existing system and the cooling setpoint for the ductless heat pump should be at least 2°F 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.

⁶⁴¹ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

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.

New Federal Standards affecting heat pumps became effective January 1, 2023. The new standards effective in 2023, require any residential heat pump manufactured in, or imported into, the United States to have a minimum efficiency rating meeting the following:⁶⁴²

- Split system heat pump – 14.3 SEER2 and 7.5 HSPF2
- Single-package heat pump – 13.4 SEER2 and 6.7 HSPF2

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years.⁶⁴³

DEEMED MEASURE COST

The full installation cost for this measure should be used, if unavailable a default is provided below:⁶⁴⁴

Capacity Range	Full Install Cost (\$/ton) ⁶⁴⁵
< 1 ton	$(\$3,039 + (\$600 * (\text{HSPF2} - 7.8))) + \900
≥ 1 to < 2 tons	$(\$2,243 + (\$600 * (\text{HSPF2} - 7.8))) + \900
≥ 2 to < 3 tons	$(\$1,882 + (\$600 * (\text{HSPF2} - 7.8))) + \900
≥ 3 tons	$(\$1,157 + (\$600 * (\text{HSPF2} - 7.8))) + \900

For adding space conditioning to a new space within a home, the incremental cost should be used and is estimated below:

Capacity Range	Incremental Cost (\$/ton) ⁶⁴⁶
< 1 ton	$(\$57 + (\$600 * (\text{HSPF2} - 7.8)))$

⁶⁴² The 2023 federal standards (10 CFR 430.32(c)(5)) are in terms of an updated metric, depicted as SEER2 and HSPF2 and manufacturers must certify their products meet the standard according to the new test procedure and new metrics. The updated test method as well as the updated energy conservation standards were negotiated under the appliance standards and rulemaking federal advisory committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the negotiated rulemaking act. An equivalent stringency of these new standards for split system heat pumps are 15 SEER and 8.8 HSPF and for single-package heat pumps are 14 SEER and 8 HSPF, as detailed in: Federal Code of Regulations, Energy Conservation Program: Energy Conservation Standards for residential Central Air Conditioners and Heat Pumps; Confirmation of effective date and compliance date for direct final rule, May 26, 2017, Docket: EERE-2014-BT-STD-0048

⁶⁴³ Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

⁶⁴⁴ Cadmus, Opinion Dynamics; 'PY7 HVAC and Ductless Mini-Split Heat Pump Incremental Cost Analysis' memo for Ameren Illinois, dated September 4, 2015.

⁶⁴⁵ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Additive efficiency costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs have been determined using the difference between total installed costs and retail costs from the EIA study and are presented as additive to allow distinction as needed. See "Res HVAC Cost Update 2026" for more details.

⁶⁴⁶ Heat Pump, Central Air Conditioning, and Furnace costs are based upon MidAmerican program data from the 2024 and 2025 program years. Additive efficiency costs have been determined using ratios from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. See "Res HVAC Cost Update 2026" for more details.

≥ 1 to < 2 tons	(\$42 + (\$600 * (HSPF2 - 7.8)))
≥ 2 to < 3 tons	(\$35 + (\$600 * (HSPF2 - 7.8)))
≥ 3 tons	(\$22 + (\$600 * (HSPF2 - 7.8)))

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings

$$\Delta \text{kWh} = \Delta \text{kWh}_{\text{heat}} + \Delta \text{kWh}_{\text{cool}}$$

$$\Delta \text{kWh}_{\text{heat}} = \left[\frac{\text{Capacity}_{\text{Heat}} * \text{EFLH}_{\text{Heat}} * \text{HeatLoadFactor} * \left(\frac{1}{\text{HSPF2}_{\text{base}}} - \frac{1}{\text{HSPF2}_{\text{ee}} * \text{PD}_{\text{Adj}}} \right)}{1,000} \right] * \text{LF}$$

$$\Delta \text{kWh}_{\text{cool}} = \left[\frac{\text{Capacity}_{\text{Cool}} * \text{EFLH}_{\text{cool}} * \left(\frac{1}{\text{SEER2}_{\text{base}}} - \frac{1}{\text{SEER2}_{\text{ee}}} \right)}{1,000} \right] * \text{LF}$$

Where:

$\text{Capacity}_{\text{Heat}}$ = the heating output capacity of the ductless heat pump unit in Btu/hr.⁶⁴⁷

= Actual installed

$\text{EFLH}_{\text{Heat}}$ = Equivalent Full Load Hours for heating

= Dependent on location and application (whole house or add-on/supplementary).⁶⁴⁸ If climate zone, building type, and application are unknown, assume 1,688 hours.⁶⁴⁹

Application	Climate Zone (City Based Upon)	EFLH _{Heat} (Hours)					
		Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Whole house conditioning	Zone 5 (Burlington)	1,892	1,991	1,367	1,618	1,769	2,104
	Zone 6 (Mason City)	2,717	2,858	1,964	2,322	2,540	3,020
	Average/Unknown	2,143	2,254	1,549	1,832	2,003	2,382

⁶⁴⁷ 1 Ton = 12 kBtu/hr.

⁶⁴⁸ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Add-on / supplemental EFLH are estimated by multiplying by a factor of 70% (consistent with PA TRM 2013).

⁶⁴⁹ Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022. Additionally, distribution of application is sourced from 2022 IPL residential program participation data and 2021 – 2022 MidAmerican program participation data.

Iowa Energy Efficiency Statewide Technical Reference Manual—2.4.7 Ductless Heat Pumps

Application	Climate Zone (City Based Upon)	EFLH _{Heat} (Hours)					
		Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
	⁶⁵⁰						
Add-on / supplemental	Zone 5 (Burlington)	1,324	1,393	957	1,132	1,238	1,473
	Zone 6 (Mason City)	1,902	2,001	1,375	1,626	1,778	2,114
	Average/Unknown ⁶⁵¹	1,500	1,578	1,084	1,282	1,402	1,668

HeatLoadFactor = Portion of HeatLoad displaced by ASHP in partial displacement applications. Varies by Switchover Temperature and Climate Region. If Switchover Temperature is unknown, use 26°F.⁶⁵²
 = 1.0 If cold climate heat pump
 = 1.0 if full displacement, or if Switchover Temperature is lower than 17°F

Climate Zone (City Based Upon)	HeatLoadFactor (by Switchover Temperature)										
	47°F	44°F	41°F	38°F	35°F	32°F	29°F	26°F	23°F	20°F	17°F
Zone 5 (Burlington)	8%	14%	20%	26%	39%	52%	59%	71%	79%	82%	89%
Zone 6 (Mason City)	6%	11%	15%	19%	25%	33%	35%	43%	49%	54%	61%
Average/ unknown	7%	12%	17%	22%	34%	46%	50%	59%	66%	71%	78%

HSPF2_{ee} = HSPF2 rating of new equipment
 = Actual installed, if unknown assume 7.8 HSPF2 (9.2 HSPF)⁶⁵³
 PD_{Adj} = Adjustment multiplier to account for increased heat pump efficiency in Partial Displacement applications when there is no electric resistance backup and Switchover Temperature is higher than 17°F. Varies by Switchover Temperature and Climate Region. If Switchover Temperature is unknown, use 26°F.⁶⁵⁴
 = 1.0 if cold climate heat pump
 = 1.0 if full displacement, or if Switchover Temperature is lower than 17°F

Climate Zone (City Based Upon)	PD _{Adj} (by Switchover Temperature)										
	47°F	44°F	41°F	38°F	35°F	32°F	29°F	26°F	23°F	20°F	17°F
Zone 5 (Burlington)	155%	151%	147%	145%	140%	136%	134%	131%	129%	128%	126%
Zone 6 (Mason City)	155%	151%	148%	145%	142%	137%	136%	132%	129%	127%	124%
Average/Unknown	155%	151%	148%	145%	139%	136%	135%	132%	129%	128%	125%

HSPF2_{base} = HSPF2 rating of existing or new baseline equipment. If using rated efficiencies, derate

⁶⁵⁰ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁶⁵¹ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁶⁵² As modeled in 'ASHP Partial Displacement Analysis 20240523.xlsx'

⁶⁵³ ENERGY STAR version 6.2, effective January 1, 2023.

⁶⁵⁴ As modeled in 'ASHP Partial Displacement Analysis 20240523.xlsx'

efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁶⁵⁵

= Actual, if unknown assume:

Existing Equipment Type	HSPFbase	HSPF2base
Electric resistance heating	3.41 ⁶⁵⁶	3.41
Air Source Heat Pump	5.44 ⁶⁵⁷	4.62
For new space conditioning, assume baseline ductless heat pump	8.8 ⁶⁵⁸	7.5

Capacity_{cool} = the cooling output capacity of the ductless heat pump unit in Btu/hr.⁶⁵⁹

= Actual installed, if unknown assume 24,896 Btu/hr⁶⁶⁰

EFLH_{cool} = Equivalent Full Load Hours for cooling. Depends on location and application (whole house v add-on / supplemental). See table below.⁶⁶¹ If climate zone, building type, and application are unknown, assume 408 hours.⁶⁶²

Application	Climate Zone (City Based Upon)	EFLH _{cool} ⁶⁶³					
		Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Whole house conditioning	5 (Burlington)	583	977	537	784	541	921
	6 (Mason City)	291	489	268	392	271	461
	Average/Unknown ⁶⁶⁴	514	861	472	690	477	811
Add-on / supplemental	5 (Burlington)	330					
	6 (Mason City)	168					

⁶⁵⁵ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁶⁵⁶ Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.

⁶⁵⁷ 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.

⁶⁵⁸ Converted federal baseline HSPF2 equivalent.

⁶⁵⁹ 1 Ton = 12 kBtu/hr.

⁶⁶⁰ Based on average of all available models on AHRI directory, as accessed on 04/01/2022. See ‘AHRI_20220401_VSMS.xlsx’ for more detail.

⁶⁶¹ Residential EFLH for room AC.

⁶⁶² Based on distribution of building types from IPL residential prescriptive program from April 2019 through March 2022. Additionally, distribution of application is sourced from 2022 IPL residential program participation data and 2021 – 2022 MidAmerican program participation data.

⁶⁶³ 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) 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.) In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values.

⁶⁶⁴ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Application	Climate Zone (City Based Upon)	EFLH _{cool} ⁶⁶³					
		Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
	Average/Unknown ⁶⁶⁵	292					

SEER2_{ee} = SEER2 rating of new equipment

= Actual installed, if unknown assume 15.2 SEER2 (15.9 SEER)⁶⁶⁶

SEER2_{base} = SEER2 rating of existing equipment

= Use actual value. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ⁶⁶⁷ If unknown, see table below.

Existing Cooling System	SEER_base	SEER2_base
Air Source Heat Pump	9.12	8.66
Central AC	8.60 ⁶⁶⁹	8.2
Room AC	8.0 ⁶⁷⁰	7.6
No cooling ⁶⁷¹	Set '1/SEER_exist' = 0	Set '1/SEER2_exist' = 0
For new space conditioning, assume baseline ductless heat pump	15 ⁶⁷²	14.3

LF = Load Factor accounting for DHP operating at partial loads and to calibrate savings to findings from evaluations

= 25%⁶⁷³

⁶⁶⁵ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁶⁶⁶ ENERGY STAR version 6.2, effective January 1, 2023.

⁶⁶⁷ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

⁶⁶⁸ 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. Converted to SEER2.

⁶⁶⁹ Ibid.

⁶⁷⁰ Estimated by converting the EER2 assumption using the conversion equation; EER2_base = (-0.02 * SEER2_base²) + (1.12 * SEER2). From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Master's Thesis, University of Colorado at Boulder.

⁶⁷¹ 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.

⁶⁷² Based on federal standard baseline, converted to SEER.

⁶⁷³ Factor used by Cadmus, and supported by findings in Cadmus "Ductless Mini-Split Heat Pump Impact Evaluation," December 30, 2016.

For example, installing a 1.5-ton (heating and cooling capacity) ductless heat pump unit rated at 7.8 HSPF and 15.2 SEER in a single-family home in unknown location to displace electric baseboard heat load and replace a window air conditioner in a full displacement application, savings are:

$$\begin{aligned}\Delta \text{kWh}_{\text{heat}} &= ((18,000 * 2254 * 1 * (1/3.41 - 1/7.8 * 1)) / 1,000) * 0.25 \\ &= 1,674.1 \text{ kWh} \\ \Delta \text{kWh}_{\text{cool}} &= ((18,000 * 310 * (1/7.6 - 1/15.2)) / 1,000) * 0.25 \\ &= 91.8 \text{ kWh} \\ \Delta \text{kWh} &= 1,674.1 + 91.8 \\ &= 1,765.9 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \left[\frac{\text{Capacity}_{\text{Cool}} * \left(\frac{1}{\text{EER2}_{\text{exist}}} - \frac{1}{\text{EER2}_{\text{ee}}} \right) * CF}{1,000} \right]$$

Where:

$\text{EER2}_{\text{base}}$ = Energy Efficiency Ratio 2 of existing cooling system (kBtu/hr/kW)
= Use actual EER2 rating. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁶⁷⁴ If unknown assume:

Existing Cooling System	EER_base	EER2_base
Air Source Heat Pump	8.55	8.12
Central AC	8.15 ⁶⁷⁶	7.74
Room AC	7.7 ⁶⁷⁷	7.32
No central cooling ⁶⁷⁸	Set '1/EER_exist' = 0	Set '1/EER2_exist' = 0
For new space conditioning, assume baseline ductless heat pump	8.32 ⁶⁷⁹	8

EER2_{ee} = Energy Efficiency Ratio 2 of new ductless Air Source Heat Pump (kBtu/hr / kW)

= Actual, If not provided convert SEER2 to EER2 using this formula:

$$\text{EER2} = (-0.02 * \text{SEER2}^2) + (1.12 * \text{SEER2})$$

⁶⁷⁴ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁶⁷⁵ 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. Converted to EER2.

⁶⁷⁶ Ibid.

⁶⁷⁷ Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report." Converted to EER2.

⁶⁷⁸ 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.

⁶⁷⁹ Based on the lowest EER2 of available non-qualifying units on the CAC database, as accessed on 03/20/2025.

	= If EER2 and SEER2 are unknown assume 11.44 EER, 11 EER2 ⁶⁸⁰
CF	= Summer System Peak Coincidence Factor for Cooling
	For supplemental or limited zonal cooling = 43.1% ⁶⁸¹
	For whole house cooling = 72% ⁶⁸²
	For unknown application =48.6% ⁶⁸³

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-V08-270101

SUNSET DATE: 1/1/2030

⁶⁸⁰ Based on ENERGY STAR version 6.2 EER2 requirement.

⁶⁸¹ Based on analysis of metering results from Ameren Illinois; Cadmus, “All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems”, October 6, 2015.

⁶⁸² 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)’.

⁶⁸³ Distribution of application is sourced from 2022 IPL residential program participation data and 2021 – 2022 MidAmerican program participation data.

2.4.8 Energy Recovery Ventilator

DESCRIPTION

An energy recovery ventilator (ERV) saves energy in a home ventilation system by preconditioning outside air with heated or cooled exhaust air before it is returned outside. While a Heat Recovery Ventilator (HRV) can recover sensible heat, 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.⁶⁸⁴

DEEMED MEASURE COST

The actual install cost (including labor) for this measure should be used, if unknown use \$2300.⁶⁸⁵

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

⁶⁸⁴ Assumed service life limited by controls - "Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy

⁶⁸⁵ The average of \$800 and \$1100, the costs associated with average and high efficiency ERVs as per the Minnesota Sustainable Housing Initiative plus \$1350 (average of \$1200 and 1500) for installation labor costs.

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling load due to ERV recovery

For units with cooling capacities less than 65 kBtu/hr:

$$\Delta kWh_{cooling} = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{SEER2_{exist}} \right)}{1,000} \right] * RF_{cool}$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWh_{cooling} = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{IEER_{exist}} \right)}{1,000} \right] * RF_{cool}$$

Where:

$EFLH_{cool}$ = Equivalent Full load cooling hours

= Dependent on location:⁶⁸⁶

Climate Zone (City Based Upon)	EFLH _{cool} (Hours)	
	Single Family New	Manufactured New
Zone 5 (Burlington)	583	541
Zone 6 (Mason City)	291	271
Average/Unknown	514	477

$Capacity_{cool}$ = Cooling output capacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)
= Actual installed

$SEER2_{exist}$ = Seasonal Energy Efficiency Ratio 2 of existing unit (kBtu/kWh)⁶⁸⁷
= 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
= 9%⁶⁸⁸

$\Delta kWh_{heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to ERV recovery

⁶⁸⁶ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁶⁸⁷ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

⁶⁸⁸ 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.

$$\Delta kWh_{heating} = \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{HSPF2_{exist}} \right)}{1,000} \right] * RF_{heat}$$

Where:

$EFLH_{Heat}$ = Equivalent Full load hours of heating
 = Dependent on location:⁶⁸⁹

Climate Zone (City Based Upon)	EFLH _{Heat} (Hours)	
	Single Family New	Manufactured New
Zone 5 (Burlington)	1,892	1,769
Zone 6 (Mason City)	2,717	2,540
Average/Unknown	2,143	2,003

$Capacity_{Heat}$ = Heating output capacity of equipment in (Btu/hr)
 = Actual (where 1 ton = 12,000 Btu/hr)

$HSPF2_{Exist}$ = Heating System Performance Factor of existing heating system (kBtu/kWh)⁶⁹⁰
 = Actual. Note: resistance heat will have an HSPF2 of 3.412⁶⁹¹

1000 = Converts Btu to kBtu

RF_{heat} = Recovery factor, expressed as a percentage of total design load reduction for heating
 = 10%⁶⁹²

For example, an ERV installed in a new single family home in Mason City with 3 ton 16 SEER2, 12.5 EER2, 9 HSPF2 ducted air source heat pump.

$$\Delta kWh_{cooling} = ((291 * 36,000 * (1/16))/1,000) * 0.09$$

$$= 58.9 \text{ kWh}$$

$$\Delta kWh_{heating} = ((2,717 * 36,000 * (1/9))/1,000) * 0.10$$

$$= 1,086.8 \text{ kWh}$$

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

$$= 58.9 + 1,086.8$$

$$= 1,145.7 \text{ kWh}$$

⁶⁸⁹ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁶⁹⁰ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

⁶⁹¹ Electric resistance heating is assumed to provide 100% of its power as usable heat. This results in an HSPF of 3.412, as 1kWh is equal to 3,412 btuh.

⁶⁹² 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 ASHP⁶⁹³

Other factors as defined above.

For example, an ERV installed in a new single family home in Mason City with 3 ton 16 SEER2, 12.5 EER2, 9 HSPF2 ducted air source heat pump.

$$\begin{aligned}\Delta kW &= 58.9/291 * 0.68 \\ &= 0.1376 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

Δ Therms (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:⁶⁹⁴

Climate Zone (City Based Upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	754	869	526	738	641	890
Zone 6 (Mason City)	1,084	1,246	755	1,059	921	1,277
Average/Unknown	854	983	596	835	726	1,007

η_{Heat} = Efficiency of heating system
= Actual⁶⁹⁵

100,000 = Converts Btu to Therms

⁶⁹³ 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)'.

⁶⁹⁴ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁶⁹⁵ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

Other factors as defined above.

For example, an ERV installed in a new single family home in Mason City with 90,000 Btu, 95% AFUE gas furnace.

$$\begin{aligned}\Delta\text{Therms} &= ((1,084 * 90,000) / (0.95 * 100,000)) * 0.10 \\ &= 102.7 \text{ Therms}\end{aligned}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating⁶⁹⁶

= 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 90,000 Btu, 95% AFUE gas furnace.

$$\begin{aligned}\Delta\text{Therms} &= 102.7 * 0.016525 \\ &= 1.697 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ERVE-V06-260101

SUNSET DATE: 1/1/2029

⁶⁹⁶ 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 minimum efficiency rating of 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 a minimum efficiency rating of 65% AFUE.⁶⁹⁷

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a gas fireplace is assumed to be 20 years.⁶⁹⁸

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 \$318 and the incremental installation cost is \$23. Total incremental cost is \$341.⁶⁹⁹

LOADSHAPE

N/A

Coincidence Factor

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

⁶⁹⁷ The distinct class of “vented hearth heater” product was ordered to be vacated by the DOE in *Hearth, Patio & Barbecue Association et al v. Department of Energy*, 706 F.3d 499 (D.C. Cir. 2013). In response, “DOE explained that these products (hearth heaters) are appropriately covered as vented home heating equipment” (87 FR 6788). To support this measure, the current federal efficiency standards listed in 10 CFR 430.32(i) for “gas wall gravity <27,000 btu/h” category of product will be used as baseline equipment efficiency.

⁶⁹⁸ *InterNachi’s Standard Estimated Life Expectancy Chart for Homes*. International Association of Certified Home Inspectors. Accessed March 3, 2023.

⁶⁹⁹ 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. Adjusted for inflation.

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = Capacity_{output} * \left(\frac{1}{eff_b} - \frac{1}{eff_e} \right) * Hours\ of\ Use * 0.01$$

Where:

$Capacity_{output}$	= Output Capacity in kBTU
	= Actual, if unknown assume 37kBTU
eff_b	= Efficiency of baseline equipment
	= 65%
eff_e	= Efficiency of new unit
	= Actual, if unknown assume 70%
$Hours\ of\ Use$	= 135 ⁷⁰⁰
0.01	= Conversion factor kBTU to Therms

Using default assumptions, deemed savings is:

$$\begin{aligned} \Delta Therms &= 37 * (1/0.65 - 1/0.70) * 135 * 0.01 \\ &= 5.5 \text{ Therms} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$	= Therm impact calculated above
GCF	= Gas Coincidence Factor for Heating ⁷⁰¹
	= 0.016525 for Residential Space Heating (other)

Using default assumptions, deemed savings is:

$$\begin{aligned} \Delta PeakTherms &= 5.5 * 0.016525 \\ &= 0.0909 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GASF-V03-240101

SUNSET DATE: 1/1/2030

⁷⁰⁰ This value was calculated using the data available on the Hearth Patio & Barbecue Association website that a typical fireplace is used 52 times a year and with an average usage time of 2.6 hours.

⁷⁰¹ 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.⁷⁰²

DEEMED MEASURE COST

For all project types, full installation costs should be used for screening purposes.

LOADSHAPE

Loadshape RE11 – Residential Single Family Vent

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings are deemed based on building type and vintage.⁷⁰³

Building Type	Vintage	Annual Energy Savings kWh
Manufactured	Existing	284
Manufactured	New	155
Single Family	Existing	343

⁷⁰² 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.

⁷⁰³ 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	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***

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

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 a tune up of a Central ASHP and should include a thorough cleaning, the measurement of refrigerant charge levels and airflow, correction of any problems found and post-treatment re-measurement.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a residential heat pump ($\leq 65,000$ Btu/hr) that has not been serviced for at least 3 years.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the tune up is assumed to be 3 years.⁷⁰⁴

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune-up.

If actual costs are unknown, assume a measure cost of \$95⁷⁰⁵.

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left[\frac{EFLH_{cool} * RatedCapacity_{cool} * \left(\frac{SF_{cool}}{RatedSEER} \right)}{1,000} \right] + \left[\frac{EFLH_{heat} * RatedCapacity_{heat} * \left(\frac{SF_{heat}}{RatedHSPF} \right)}{1,000} \right]$$

Where:

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

⁷⁰⁴ Based on DEER 2014 EUL Table for “Clean Condenser Coils – Residential” and “Refrigerant Charge – Residential”.

⁷⁰⁵ Average labor and parts costs paid by Alliant Energy customers who had their central air source heat pump systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations

= Dependent on location:⁷⁰⁶

Climate Zone (City Based Upon)	EFLH _{cool} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/Unknown	861	690	811

RatedCapacity_{cool} = Rated Cooling output capacity of Air Source Heat Pump (Btu/hr)

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

= If actual capacity is unknown, assume 32,113 Btu/hr⁷⁰⁷

SF_{cool} = Cooling Savings Factor for ASHP tune-ups

=7.5%⁷⁰⁸

RatedSEER = Rated Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

= Actual. If unknown assume 14.5 SEER2 (15.3 SEER)⁷⁰⁹

SF_{heat} = Heating Savings Factor for ASHP tune-ups

=2.3%⁷¹⁰

EFLH_{Heat} = Equivalent Full load hours of heating

= Dependent on location:⁷¹¹

Climate Zone (City Based Upon)	EFLH _{Heat} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	1,991	1,618	2,104
Zone 6 (Mason City)	2,858	2,322	3,020
Average/Unknown	2,254	1,832	2,382

RatedCapacity_{Heat} = Rated Heating output capacity of Air Source Heat Pump (Btu/hr)

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

⁷⁰⁶ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷⁰⁷ Average cooling capacity of Alliant Energy customers who had their central air source heat pump systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations

⁷⁰⁸ 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.

⁷⁰⁹ Average SEER rating of Alliant Energy customers who had their central air source heat pump systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations, converted to SEER2 by multiplying by 0.95.

⁷¹⁰ 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.

⁷¹¹ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

= If actual capacity is unknown, assume 32,454 Btu/hr⁷¹²

RatedHSPF = Rated Heating System Performance Factor of existing heating system (kBtu/kWh)
= Actual; if unknown assume 5.78 HSPF2 (6.8 HSPF)⁷¹³

For example, for a 2 ton air source heat pump with rated efficiency of 14 SEER, 12 EER, 9 HSPF undergoing a tune-up in an existing single family home in unknown location:

$$\begin{aligned}\Delta kWh &= ((861 * 24,000 * 0.075/14)/1,000) + ((2,254 * 24,000 * 0.023/9)/1,000) \\ &= 110.7 + 138.2 \\ &= 248.9 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{\text{RatedCapacity}_{cool} * \left(\frac{SF_{cool}}{\text{RatedEER}} \right)}{1,000} \right] * CF$$

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:

$$\text{EER} = (-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$$

= Alternatively, if actual EER rating is unknown, assume 11.37 EER2 (11.97EER)⁷¹⁴

CF = Summer System Peak Coincidence Factor for Cooling
= 72%⁷¹⁵

For example, for a 2 ton, 14 SEER, 12 EER, 9 HSPF air source heat pump undergoing a tune-up in an existing single family home in unknown location:

$$\begin{aligned}\Delta kW &= (24,000 * 0.075/12)/1,000 * 72\% \\ &= 0.108 kW\end{aligned}$$

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-

⁷¹² Average heating capacity of Alliant Energy customers who had their central air source heat pump systems serviced between 2019 and 2025, please see "2019-2025 Tune Up Measures.xlsx" for calculations

⁷¹³ Use actual HSPF rating where it is possible to measure or reasonably estimate. Unknown default of 6.8 HSPF is a VEIC estimate based on minimum Federal Standard between 1992 and 2006, converted to HSPF2 by multiplying by 0.85.

⁷¹⁴ Average EER rating of Alliant Energy customers who had their central air source heat pump systems serviced between 2019 and 2025, please see "2019-2025 Tune Up Measures.xlsx" for calculations, converted to EER2 by multiplying by 0.95.

⁷¹⁵ 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)'.

up measure. This benefit is therefore conservatively excluded.

MEASURE CODE: RS-HVC-ATUN-V06-250101

SUNSET DATE: 1/1/2028

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 a tune up of a Central Air Conditioner and should include a thorough cleaning, the measurement of refrigerant charge levels and airflow, correction of any problems found and post-treatment re-measurement.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a central air conditioner with a capacity up to 135,000 Btu/hr that has not been serviced for at least 3 years.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the tune-up is assumed to be 3 years.⁷¹⁶

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune-up.

If actual costs are unobtainable, assume a deemed measure cost of \$91.1⁷¹⁷.

LOADSHAPE

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE02 – Residential Multifamily Cooling

⁷¹⁶ Based on DEER 2014 EUL Table for “Clean Condenser Coils – Residential” and “Refrigerant Charge – Residential”.

⁷¹⁷ Average labor and parts costs paid by Alliant Energy customers who had their central air conditioner systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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:⁷¹⁸

Climate Zone (City based upon)	EFLH _{cool} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

$RatedCapacity_{cool}$ = Rated cooling output capacity (Btu/hr)

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

= If actual capacity unknown, assume 29,088 Btu/hr⁷¹⁹

SF_{cool} = Cooling Savings Factor for CAC tune-ups

= 7.5%⁷²⁰

$RatedSEER$ = Rated Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

= Actual. If unknown assume 11.7 SEER2 (12.34 SEER)⁷²¹

$RatedIEER$ = Rated Integrated Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

= Actual

⁷¹⁸ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷¹⁹ Average cooling capacity of Alliant Energy customers who had their central air conditioner systems serviced between 2019 and 2025, please see "2019-2025 Tune Up Measures.xlsx" for calculations.

⁷²⁰ 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.

⁷²¹ Average SEER rating of Alliant Energy customers who had their central air conditioner systems serviced between 2019 and 2025, please see "2019-2025 Tune Up Measures.xlsx" for calculations, converted to SEER2 by multiplying by 0.95.

For example, for a three ton CAC unit with rated efficiency 15 SEER, 12 EER undergoing a tune-up in a single family home in unknown location:

$$\begin{aligned}\Delta kWh &= (861 * 36,000 * 0.075/15)/ 1,000 \\ &= 155 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{\text{RatedCapacity}_{Cool} * \left(\frac{SF_{cool}}{\text{RatedEER}} \right)}{1,000} \right] * CF$$

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:
 $EER = (-0.02 * SEER^2) + (1.12 * SEER)$
 = Alternatively, if actual EER rating is unknown, assume 10.8 EER2 (11.26 EER)⁷²²
- CF = Summer System Peak Coincidence Factor for Cooling
 = 68%⁷²³

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-CTUN-V06-250101

SUNSET DATE: 1/1/2028

⁷²² Average EER rating of Alliant Energy customers who had their central air conditioner systems serviced between 2019 and 2025, please see "2019-2025 Tune Up Measures.xlsx" for calculations, converted to EER2 by multiplying by 0.95.

⁷²³ 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 SAVINGS**ELECTRIC ENERGY SAVINGS**

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{Capacity * EFLH * \left(\frac{Eff_{before} + E_i}{Eff_{before}} - 1 \right)}{100,000}$$

Where:

Capacity = Boiler gas input size (Btu/hr)
 = Actual
 EFLH = Equivalent Full Load Hours for heating
 = Dependent on location:⁷²⁴

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	754	869	526	738	641	890
Zone 6 (Mason City)	1084	1246	755	1059	921	1277
Average/unknown	854	983	596	835	726	1007

⁷²⁴ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Effbefore	= Combustion efficiency of the boiler before the tune-up ⁷²⁵
	= 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 an unknown location 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:

$$\Delta \text{therms} = (100,000 * 983 * (((0.82 + 0.018) / 0.82) - 1)) / 100,000$$

$$= 21.6 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * \text{GCF}$$

Where:

ΔTherms	= Therm impact calculated above
GCF	= Gas Coincidence Factor for Heating ⁷²⁶
	= 0.014378 for Residential Boiler

For example, for a 100 kBtu boiler in an unknown location 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:

$$\Delta \text{PeakTherms} = 21.6 * 0.014378$$

$$= 0.3106 \text{ therms}$$

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-V04-250101

SUNSET DATE: 1/1/2028

⁷²⁵ 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.

⁷²⁶ 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.

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.

DEFINITION OF BASELINE EQUIPMENT

The baseline for tune-up is a furnace assumed not to have had a tune-up in the past 2 years.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life of a tune-up is 2 years.⁷²⁷

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

⁷²⁷ Based on VEIC professional judgment.

Algorithms

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta Therms * Fe * 29.3$$

Where:

$\Delta Therms$ = as calculated below

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
= 3.14%⁷²⁸

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{CAP_{Input} * EFLH * \left(\frac{Eff_{before} + E_i}{Eff_{before}} - 1 \right)}{100,000}$$

Where:

CAP_{Input} = Gas Furnace input capacity (Btuh)
= Actual rated capacity

$EFLH$ = Equivalent Full Load Hours for heating
= Dependent on location:⁷²⁹

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	754	869	526	738	641	890
Zone 6 (Mason City)	1,084	1,246	755	1,059	921	1,277
Average/	854	983	596	835	726	1,007

⁷²⁸ 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 (E_f in MMBtu/yr) and E_{ae} (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.

⁷²⁹ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
unknown						

Effbefore = Combustion Efficiency of the furnace before the tune-up

= Actual

EI = Combustion Efficiency Improvement of the furnace tune-up measure⁷³⁰

= Actual

100,000 = Converts Btu to therms

For example, for a 100 kBtu furnace in an unknown location 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:

$$\Delta \text{Therms} = (100,000 * 983 * (((0.82 + 0.018) / 0.82) - 1)) / 100,000$$

$$= 21.6 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating⁷³¹

= 0.016525 for Residential Space Heating (other)

For example, for a 100 kBtu furnace in an unknown location 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:

$$\Delta \text{PeakTherms} = 21.6 * 0.016525$$

$$= 0.3570 \text{ therms}$$

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.

⁷³⁰ 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.

⁷³¹ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

MEASURE CODE: RS-HVC-FTUN-V05-250101

SUNSET DATE: 1/1/2028

2.4.15 Geothermal Source Heat Pump Tune-Up

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 a tune up of a GSHP and should include a thorough cleaning, the measurement of refrigerant charge levels and airflow, correction of any problems found and post-treatment re-measurement.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a residential GSHP that has not been serviced for at least 3 years.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the tune up is assumed to be 3 years.⁷³²

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune-up.

If actual costs are unobtainable, assume a deemed measure cost of \$149⁷³³.

LOADSHAPE

Loadshape RE08 – Residential Single Family Heat Pump

⁷³² Based on DEER 2014 EUL Table for “Clean Condenser Coils – Residential” and “Refrigerant Charge – Residential”.

⁷³³ Average labor and parts costs paid by Alliant Energy customers who had their geothermal source heat pump systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{SF_{Cool}}{EER_{PL}} \right) + FLF_{Cool} * \left(\frac{SF_{Cool}}{EER_{FL}} \right) \right)}{1,000} \right]$$

$$+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{SF_{Heat}}{(COP_{PL} * 3.412)} \right) + FLF_{Heat} * \left(\frac{SF_{Heat}}{(COP_{FL} * 3.412)} \right) \right)}{1,000} \right]$$

Where:

EFLH_{Cool} = Full load cooling hours
= Dependent on location:⁷³⁴

Climate Zone (City based upon)	EFLH _{Cool} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

Capacity_{Cool} = Cooling output capacity of Geothermal Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000 Btu/hr)
= If actual capacity unknown, assume 49,178 Btu/hr⁷³⁵

PLF_{Cool} = Part load cooling mode operation
= 0.85⁷³⁶ if variable speed GSHP
= 0 if single/constant speed GSHP

SF_{Cool} = Cooling Savings Factor for GSHP tune-ups
= 7.5%⁷³⁷

⁷³⁴ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷³⁵ Average cooling capacity of Alliant Energy customers who had their geothermal source heat pump systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations

⁷³⁶ 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.

⁷³⁷ 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

FLF_{Cool}	= Equivalent full load cooling mode operation factor ⁷³⁸ = 0.15 if variable speed GSHP = 1 if single/constant speed GSHP
EER_{PL}	= Part load Energy Efficiency Ratio (EER) of efficient GSHP unit = 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 ⁷³⁹ :

Climate Zone (City based upon)	EFLH _{Heat} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	1991	1618	2104
Zone 6 (Mason City)	2858	2322	3020
Average/ unknown	2254	1832	2382

$Capacity_{Heat}$	= Full load heating output capacity of Geothermal Source Heat Pump (Btu/hr) = Actual (1 ton = 12,000 Btu/hr) = If actual capacity unknown, assume 43,147 Btu/hr ⁷⁴⁰
PLF_{Heat}	= Part load heating mode operation = 0.5 ⁷⁴¹ if variable speed GSHP = 0 if single/constant speed GSHP
FLF_{Heat}	= Full load heating mode operation factor ⁷⁴² = 0.5 if variable speed GSHP = 1 if single/constant speed GSHP
SF_{Heat}	= Heating Savings Factor for ASHP tune-ups

⁷³⁸ 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.

⁷³⁹ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷⁴⁰ Average heating capacity of Alliant Energy customers who had their geothermal source heat pump systems serviced between 2019 and 2025, please see “2019-2025 Tune Up Measures.xlsx” for calculations.

⁷⁴¹ 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.

⁷⁴² 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.

	=2.3% ⁷⁴³
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)

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 unknown location:

$$\begin{aligned}\Delta \text{kWh} &= (861 * 36,000 * (0.85 * (7.5\%/20) + 0.15 * (7.5\%/18))/1,000) + (2,254 * 36,000 * (0.5 * \\ &\quad (2.3\%/4.4 * 3.412) + 0.5 * (2.3\%/3.4 * 3.412))/1,000) \\ &= 261 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{\text{Capacity}_{\text{cool}} * \left(\frac{SF_{\text{cool}}}{EER} \right)}{1,000} \right] * CF$$

Where:

EER	= Energy Efficiency Ratio (EER) of existing cooling system (kBtuh/kW)
	= Actual Installed
CF	= Summer system peak Coincidence Factor for cooling
	= 72% ⁷⁴⁴

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 unknown location:

$$\begin{aligned}\Delta kW &= (36,000 * (7.5\%/18))/1,000 * 72\% \\ &= 0.1080 \text{ kW}\end{aligned}$$

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.

⁷⁴³ 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.

⁷⁴⁴ 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)'.

DEEMED MEASURE CODE: RS-HVC-ASHP-TUN-V04-250101

SUNSET DATE: 1/1/2028

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 duct area 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 associated 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 (see SharePoint Reference Folder). 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 or semi-conditioned space in the home. An unconditioned space is defined as a space outside of the thermal envelope of the building that is not intentionally heated for occupancy (e.g., ventilated attic with floor insulation, vented crawlspace, unheated garages). A semi-conditioned space is defined as a space within the thermal envelope that is not intentionally heated for occupancy and is unventilated (e.g. unfinished basement).⁷⁴⁵

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of this measure is 20 years.⁷⁴⁶

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

⁷⁴⁵ Definition matches Regain factor discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012

⁷⁴⁶ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

Loadshape RE08 – Residential Single Family Heat Pump

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:

$$\text{Duct Leakage (CFM50}_{DL}) = (\text{CFM50}_{\text{Whole House}} - \text{CFM50}_{\text{Envelope Only}}) * \text{SCF}$$

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: ⁷⁴⁷

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

⁷⁴⁷ Energyconservatory.com “Minneapolis Blower Door™” Operation Manual, August 2012.

- b. Calculate duct leakage reduction, convert to CFM25_{DL}⁷⁴⁸, and factor in Supply and Return Loss Factors:

$$\text{Duct Leakage Reduction } (\Delta \text{CFM25}_{\text{DL}}) = (\text{Pre CFM50}_{\text{DL}} - \text{Post CFM50}_{\text{DL}}) * 0.64 * (\text{SLF} + \text{RLF})$$

Where:

0.64	= Converts CFM50 _{DL} to CFM25 _{DL} ⁷⁴⁹
SLF	= Supply Loss Factor ⁷⁵⁰
	= % leaks sealed located in Supply ducts * 1
	Default = 0.5 ⁷⁵¹
RLF	= Return Loss Factor ⁷⁵²
	= % leaks sealed located in Return ducts * 0.5
	Default = 0.25 ⁷⁵³

- c. Calculate Energy Savings:

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

$$\Delta kWh_{\text{cooling}} = \frac{\frac{\Delta \text{CFM25}_{\text{DL}}}{(\text{CapacityCool} / 12,000 * 400)} * \text{TRF}_{\text{Cool}} * \text{EFLH}_{\text{Cool}} * \text{CapacityCool}}{1,000 * \eta_{\text{Cool}}}$$

$$\Delta kWh_{\text{Fan}} = (\Delta \text{Therms} * Fe * 29.3)$$

Where:

$\Delta \text{CFM25}_{\text{DL}}$	= Duct leakage reduction in CFM25
CapacityCool	= Output capacity of Air Cooling system (Btu/hr)
	= Actual
12,000	= Converts Btu/H capacity to tons
400	= Conversion of Capacity to CFM (400CFM / ton) ⁷⁵⁴
TRF _{cool}	= Thermal Regain Factor for cooling by space type. This accounts for the fact that not all

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

⁷⁴⁹ 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).

⁷⁵⁰ 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.

⁷⁵¹ Assumes 50% of leaks are in supply ducts.

⁷⁵² 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.

⁷⁵³ Assumes 50% of leaks are in return ducts.

⁷⁵⁴ This conversion is an industry rule of thumb; e.g., see reference file “61-Why 400 CFM per ton.”

cool air in semi-conditioned spaces is lost to the atmosphere and will provide useful conditioning⁷⁵⁵.

= 1.0 for Unconditioned Spaces

= 0.4 for Semi-Conditioned Spaces⁷⁵⁶

EFLH_{cool} = Equivalent Full Load Cooling Hours

= Dependent on location:⁷⁵⁷

Climate Zone (City based upon)	EFLH _{cool} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/Unknown	861	690	811

1,000 = Converts Btu to kBtu

η_{Cool} = Efficiency in SEER2 of Air Conditioning equipment⁷⁵⁸

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁷⁵⁹ If not available, use:⁷⁶⁰

Equipment Type	Age of Equipment	Product Class	SEER2 Estimate
Central AC	Before 2006	Split Systems	9.5
		Single-Package Systems	9.3
	2006-2014	Split and Single-Package Systems	12.4
	2015-2022	Split Systems	12.4
		Single-Package Systems	13.3
Heat Pump	2023 on	Split and Single-Package Systems	13.4
	Before 2006	Split Systems	9.5
		Single-Package Systems	9.3
	2006-2014	Split and Single-Package Systems	12.4
	2015-2022	Split and Single-Package Systems	12.2
	2023 on	Split Systems	14.3

⁷⁵⁵ Definition of unconditioned areas is a space outside the thermal envelope (e.g., ventilated attic with floor insulation, vented crawlspace, unheated garages) and semi-conditioned (defined as a space within the thermal envelope that is not intentionally heated for occupancy and is unventilated e.g. unfinished basement).

⁷⁵⁶ Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

⁷⁵⁷ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷⁵⁸ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

⁷⁵⁹ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

⁷⁶⁰ Default cooling efficiencies are based on the minimum equipment efficiency ratings, at the time of manufacturing, for consumer heat pumps and central air conditioners, as sourced from the U.S. DOE Code of Federal Appliances, Energy Conservation Standards (CFR 430.32(c)(3). 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute

		Single-Package Systems	13.4
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Δ Therms = Therm savings as calculated in Natural Gas Savings

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
= 3.14%⁷⁶¹

29.3 = kWh per therm

For example, for duct sealing in unconditioned space in a single family house in Burlington with a 36,000 Btu/H, SEER2 10.5 Central Air Conditioner, an 80% AFUE, 105,000 Btu/H natural gas furnace, and the following blower door test results:

Before: CFM50_{Whole House} = 4,800 CFM50

CFM50_{Envelope Only} = 4,500 CFM50

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

After: CFM50_{Whole House} = 4,600 CFM50

CFM50_{Envelope Only} = 4,500 CFM50

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

Duct Leakage:

CFM50_{DL before} = (4,800 – 4,500) * 1.29
= 387 CFM

CFM50_{DL after} = (4,600 – 4,500) * 1.39
= 139 CFM

Duct Leakage reduction at CFM25:

Δ CFM25_{DL} = (387 – 139) * 0.64 * (0.5 + 0.25)
= 119 CFM25

Energy Savings:

Δ kWh = [((119 / ((36,000/12,000) * 400)) * 1 * 977 * 36,000) / (1,000 * 10.5)] + [51.6 * 0.0314 * 29.3]
= 332.2 + 47.5
= 379.7 kWh

Claiming Heating savings for homes with electric heat (Heat Pump):

$$\Delta kWh = \frac{\Delta CFM25_{DL}}{(CapacityHeat/12,000 * 400)} * TRF_{Heat} * EFLHelectricheat * CapacityHeat$$

$$= \frac{\Delta CFM25_{DL}}{\eta_{Heat} * 3,412}$$

Where:

Δ CFM25_{DL} = Duct leakage reduction in CFM25

⁷⁶¹ 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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1,495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e .

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

TRF_{heat} = Thermal Regain Factor for heating by space type. This accounts for the fact that not all heat loss in semi-conditioned spaces is lost to the atmosphere and will provide useful conditioning⁷⁶².
= 0.40 for Semi-Conditioned Spaces
= 1.0 for Unconditioned Spaces⁷⁶³

EFLHelectriceat = Equivalent Full Load Heating Hours for ASHP
= Dependent on location⁷⁶⁴:

Climate Zone (City based upon)	EFLHelectriceat		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	1,991	1,618	2,104
Zone 6 (Mason City)	2,858	2,322	3,020
Average/ unknown	2,254	1,832	2,382

η_{Heat} = Efficiency in COP of Heating equipment⁷⁶⁵
= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁷⁶⁶ If not available, use:⁷⁶⁷

System Type	Age of Equipment	Product Class	HSPF2 Estimate	COP	η _{Heat} ⁷⁶⁸
Heat Pump	Before 2006	Split Systems	5.8	1.69	1.7
		Single-Package Systems	5.6	1.64	1.64
	2006-2014	Split and Single-Package Systems	6.5	1.92	1.92
	2015-2022	Split Systems	7	2.04	2.04
		Single-Package Systems	6.8	1.99	1.99

⁷⁶² Definition of unconditioned areas is a space outside the thermal envelope (e.g., ventilated attic with floor insulation, vented crawlspace, unheated garages) and semi-conditioned (defined as a space within the thermal envelope that is not intentionally heated for occupancy and is unventilated e.g. unfinished basement).

⁷⁶³ Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

⁷⁶⁴ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷⁶⁵ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

⁷⁶⁶ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁷⁶⁷ Default cooling efficiencies are based on the minimum equipment efficiency ratings, at the time of manufacturing, for consumer heat pumps and central air conditioners, as sourced from the U.S. DOE Code of Federal Appliances, Energy Conservation Standards (CFR 430.32(c)(3). 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute

⁷⁶⁸ An 85% distribution efficiency is applied to the heat efficiency factor to account for duct losses.

	2023 and after	Split Systems	7.5	2.2	2.2
		Single-Package Systems	6.7	1.96	1.96

3412 = Converts Btu to kWh

For example, for duct sealing in unconditioned space 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:

$$\begin{aligned}\Delta kWh_{\text{heating}} &= ((119 / ((36,000/12,000) * 1 * 400)) * 1,991 * 36,000) / (2.5 * 3,412) \\ &= 833.3 \text{ kWh}\end{aligned}$$

Methodology 2: Duct Blaster Testing

Claiming Cooling savings from reduction in Air Conditioning Load:

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

$$\Delta kWh_{\text{cooling}} = \frac{\frac{Pre_CFM25 - Post_CFM25}{CapacityCool/12,000 * 400} * TRF_{Cool} * EFLH_{Cool} * CapacityCool}{1,000 * \eta_{Cool}}$$

$$\Delta kWh_{\text{Fan}} = (\Delta Therms * Fe * 29.3)$$

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 unconditioned space in a single family house in Burlington with a 36,000 Btu/H, SEER2 10.5 Central Air Conditioner, an 80% AFUE, 105,000 Btu/H natural gas furnace, and the following duct blaster test results:

$$\begin{aligned}Pre_CFM25 &= 220 \text{ CFM25} \\ Post_CFM25 &= 80 \text{ CFM25} \\ \Delta kWh &= [(((220 - 80) / (36,000/12,000 * 400)) * 1 * 977 * 36,000) / (1,000 * 10.5)] \\ &\quad + [60.7 * 0.0314 * 29.3] \\ &= 390.8 + 55.8 \\ &= 446.6 \text{ kWh}\end{aligned}$$

Claiming Heating savings for homes with electric heat (Heat Pump):

$$\Delta kWh_{\text{heating}} = \frac{\frac{Pre_CFM25 - Post_CFM25}{CapacityCool/12,000 * 400} * TRF_{Heat} * EFLH_{Electricheat} * CapacityHeat}{\eta_{Heat} * 3,412}$$

Where:

All other variables as provided above

For example, for duct sealing in a unconditioned space 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:

$$\begin{aligned}\Delta kWh_{\text{heating}} &= (((220 - 80) / (36,000/12,000 * 1 * 400)) * 1,991 * 36,000) / (2.5 * 3,412) \\ &= 980.3 \text{ kWh}\end{aligned}$$

Methodology 3: Deemed Savings⁷⁶⁹

Claiming Cooling savings from reduction in Air Conditioning Load:

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

$$\Delta kWh_{\text{cooling}} = \text{CoolSavingsPerUnit} * \text{Duct}_{\text{Length}}$$

$$\Delta kWh_{\text{Fan}} = (\Delta \text{Therms} * Fe * 29.3)$$

Where:

CoolSavingsPerUnit = Annual cooling savings per linear foot of duct

Building Type	HVAC System	CoolSavingsPerUnit (kWh/ft)	
		Unconditioned	Semi-conditioned
Manufactured	Cool Central	0.95	0.38
Multifamily	Cool Central	0.70	0.28
Single-family	Cool Central	0.81	0.32
Manufactured	Heat Pump—Cooling	0.95	0.38
Multifamily	Heat Pump—Cooling	0.70	0.28
Single-family	Heat Pump—Cooling	0.81	0.32

Duct_{Length} = Total linear feet of duct within the home

= Actual. If unavailable a default of 142 ft for single family, 92 ft for Multifamily or 100 ft for manufactured homes can be used.⁷⁷⁰

Claiming Heating savings for homes with electric heat (Heat Pump):

$$\Delta kWh_{\text{heating}} = \text{HeatSavingsPerUnit} * \text{Duct}_{\text{Length}}$$

Where:

HeatSavingsPerUnit = Annual heating savings per linear foot of duct

Building Type	HVAC System	HeatSavingsPerUnit (kWh/ft)	
		Unconditioned	Semi-conditioned
Manufactured	Heat Pump—Cooling	5.06	2.02
Multifamily	Heat Pump—Cooling	3.41	1.36
Single-family	Heat Pump—Cooling	4.11	1.64

⁷⁶⁹ 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.

⁷⁷⁰ 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

$$\Delta kW = \frac{\Delta kWh_{cooling}}{EFLH_{cool}} * CF$$

Where:

EFLH_{cool} = Equivalent Full load cooling hours:
= Dependent on location:⁷⁷¹

Climate Zone (City based upon)	EFLH _{cool} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

CF = Summer System Peak Coincidence Factor for Cooling
= 68% if central AC, 72% if ducted ASHP⁷⁷²

NATURAL GAS SAVINGS

For homes with Natural Gas Heating:

Methodology 1: Modified Blower Door Subtraction

$$\Delta Therm = \frac{\frac{\Delta CFM25_{DL}}{CapacityHeat * 0.0136} * TRF_{Heat} * EFLH_{gasheat} * CapacityHeat * \frac{\eta_{Equipment}}{\eta_{System}}}{100,000}$$

Where:

ΔCFM25_{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)⁷⁷³
EFLH_{gasheat} = Equivalent Full load heating hours for Furnaces

⁷⁷¹ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁷⁷² 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)'.

⁷⁷³ 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 fromContracting Business website). 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.

= Dependent on location:⁷⁷⁴

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	901	1038	628	882	765	1062
Zone 6 (Mason City)	1295	1488	901	1265	1100	1525
Average/ unknown	1020	1174	712	997	867	1203

$\eta_{\text{Equipment}}$	= Heating Equipment Efficiency = Actual ⁷⁷⁵ . If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ⁷⁷⁶ – If not available, use 87% ⁷⁷⁷
η_{System}	= Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency) ⁷⁷⁸ = Actual – If not available use 74% ⁷⁷⁹
100,000	= Converts Btu to therms

⁷⁷⁴ 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. In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values.

⁷⁷⁵ 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.

⁷⁷⁶ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁷⁷⁷ 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: $(0.60 \times 0.92) + (0.40 \times 0.8) = 0.872$.

⁷⁷⁸ 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: (See: “BPI, Distribution Efficiency Table”) or by performing duct blaster testing.

⁷⁷⁹ Estimated as follows: $0.872 \times (1-0.15) = 0.74$.

For example, for duct sealing in a unconditioned space 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} = 4,800 CFM50

CFM50_{Envelope Only} = 4,500 CFM50

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

After: CFM50_{Whole House} = 4,600 CFM50

CFM50_{Envelope Only} = 4,500 CFM50

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

Duct Leakage:

$$\begin{aligned} \text{CFM50}_{\text{DL before}} &= (4,800 - 4,500) * 1.29 \\ &= 387 \text{ CFM} \end{aligned}$$

$$\begin{aligned} \text{CFM50}_{\text{DL after}} &= (4,600 - 4,500) * 1.39 \\ &= 139 \text{ CFM} \end{aligned}$$

Duct Leakage reduction at CFM25:

$$\begin{aligned} \Delta \text{CFM25}_{\text{DL}} &= (387 - 139) * 0.64 * (0.5 + 0.25) \\ &= 119 \text{ CFM25} \end{aligned}$$

Energy Savings:

$$\text{Pre Distribution Efficiency} = 1 - (387/4,800) = 92\%$$

$$\eta_{\text{System}} = 80\% * 92\% = 74\%$$

$$\begin{aligned} \Delta \text{Therm} &= ((119 / (105,000 * 0.0136)) * 1 * 1,038 * 105,000 * (0.8/0.74)) / 100,000 \\ &= 98.1 \text{ therms} \end{aligned}$$

Methodology 2: Duct Blaster Testing

ΔTherms

$$= \frac{\frac{\text{Pre_CFM25} - \text{Post_CFM25}}{\text{CapacityHeat} * 0.0136} * \text{TRF}_{\text{Heat}} * \text{EFLH}_{\text{gasheat}} * \text{CapacityHeat} * \frac{\eta_{\text{Equipment}}}{\eta_{\text{System}}}}{100,000}$$

Where:

All variables as provided above

For example, for duct sealing in an unconditioned space in a single family house in Burlington with a 36,000 Btu/H, SEER2 10.5 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

$$\begin{aligned} \Delta \text{Therms} &= (((220 - 80) / (105,000 * 0.0136)) * 1 * 1,038 * 105,000 * (0.8/0.74)) / 100,000 \\ &= 115.5 \text{ therms} \end{aligned}$$

Methodology 3: Deemed Savings⁷⁸⁰

⁷⁸⁰ 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

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

Where:

HeatSavingsPerUnit = Annual heating savings per linear foot of duct

Building Type	HVAC System	HeatSavingsPerUnit (Therms/ft)	
Manufactured	Heat Central Furnace	0.26	0.10
Multifamily	Heat Central Furnace	0.19	0.076
Single-family	Heat Central Furnace	0.21	0.084

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating⁷⁸¹

= 0.016525 for Residential Space Heating (other)

For example, for duct sealing in unconditioned space in a single family house in Burlington with a 36,000 Btu/H, SEER2 10.5 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

$\Delta PeakTherms$ = 115.5 * 0.016525

= 1.91 peak therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-DINS-V07-260101

SUNSET DATE: 1/1/2029

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.

⁷⁸¹ 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.⁷⁸²

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 \$70.⁷⁸³

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

⁷⁸² 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.

⁷⁸³ 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

$$\Delta kWh^{784} = (\%ElectricHeat * Elec_{Heating_{Consumption}} * \%Controlled * Heating_{Reduction} * Eff_{ISR}) + (\Delta Therms * Fe * 29.3)$$

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	7% ⁷⁸⁵

Elec_Heating_Consumption

= Estimate of annual household heating consumption for electrically heated homes.⁷⁸⁶ If location and heating type is unknown, assume 10,599 kWh.⁷⁸⁷

		Elec_Heating_Consumption (kWh) by Climate Zone (City based upon)		
Heating System ⁷⁸⁸	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown
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%

= If single zone thermostat in multi zone home, assume 1 / # zones

= If multi zone thermostat, assume 100%

⁷⁸⁴ Note the second part of the algorithm relates to furnace fan savings if the heating system is Natural Gas.

⁷⁸⁵ Average (default) value of 7% electric ducted heat pump space heating from NREL ResStock data for the state of 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.

⁷⁸⁶ Based on Cadmus modeling performed for the 2011 Joint Assessment.

⁷⁸⁷ 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.

⁷⁸⁸ 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 unknown, assume 93%⁷⁸⁹

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

= 6.2%⁷⁹⁰

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% ⁷⁹¹

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%⁷⁹²

29.3 = kWh per therm

Based on defaults provided above:⁷⁹³

Heating Fuel	Heating System	Building Type	ΔkWh by Climate Zone (city based upon)					
			Direct Install ⁷⁹⁴			Other Programs		
			Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown
Electrically Heated Home	Air-Source Heat Pump	Manufactured	520.7	740.2	585.1	271.2	385.5	304.7
		Multifamily	321.5	457.1	361.3	167.5	238.0	188.2
		Single-family	599.5	852.1	673.6	312.2	443.8	350.8
	Ground-Source Heat Pump	Manufactured	302.5	430.1	340.0	157.6	224.0	177.1
		Multifamily	186.5	265.1	209.5	97.1	138.0	109.1
		Single-family	347.7	494.2	390.6	181.1	257.4	203.4
Gas Heated Home	Furnace	Manufactured	24.8	35.2	27.9	12.9	18.3	14.5
		Multifamily	16.4	23.4	18.5	8.6	12.2	9.6
		Single-family	28.5	40.5	32.0	14.8	21.1	16.7
	Boiler	Manufactured	31.7	45.1	35.6	16.5	23.5	18.6

⁷⁸⁹ 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.

⁷⁹⁰ 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.

⁷⁹¹ “Programmable Thermostats. Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness,” GDS Associates, Marietta, GA. 2002GDS

⁷⁹² 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.

⁷⁹³ See “Programmable Thermostat Savings_06152023.xls” for calculation detail.

⁷⁹⁴ Assumes single zone. If not – adjust accordingly.

			ΔkWh by Climate Zone (city based upon)					
			Direct Install ⁷⁹⁴			Other Programs		
Heating Fuel	Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown
		Multifamily	25.5	36.3	28.7	13.3	18.9	14.9
		Single-family	35.3	50.1	39.6	18.4	26.1	20.6
Unknown Heat and Location			n/a	n/a	n/a	n/a	71.3	n/a

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A due to no savings from cooling during the summer peak period.

NATURAL GAS 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	93% ⁷⁹⁵

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes.⁷⁹⁶ If location is unknown, assume 578 therms.⁷⁹⁷

		Gas_Heating_Consumption (Therms) by Climate Zone (City based upon)		
Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown
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

Based on defaults provided above.⁷⁹⁸

⁷⁹⁵ Average (default) value of 93% gas space heating from NREL ResStock data for the state of 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.

⁷⁹⁶ Based on Cadmus modeling performed for the 2011 Joint Assessment.

⁷⁹⁷ 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".

⁷⁹⁸ See "Programmable Thermostat Savings_06152023.xls" for calculation detail.

		ΔTherms by Climate Zone (city based upon)					
		Direct Install ⁷⁹⁹			Other Programs		
Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/unknown	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/unknown
Heat Central Furnace	Manufactured	26.9	38.3	30.3	14.0	19.9	15.8
	Multifamily	17.9	25.4	20.1	9.3	13.2	10.5
	Single-family	30.9	44.0	34.8	16.1	22.9	18.1
Heat Central Boiler	Manufactured	34.5	49.0	38.7	18.0	25.5	20.2
	Multifamily	27.8	39.5	31.2	14.5	20.6	16.2
	Single-family	38.3	54.5	43.1	20.0	28.4	22.4
Unknown Heat and Location		n/a	n/a	31.0	n/a	n/a	17.4

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating⁸⁰⁰

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

Based on defaults provided above:

		ΔTherms by Climate Zone (city based upon)					
		Direct Install			Other Programs		
Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/unknown	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/unknown
Heat Central Furnace	Manufactured	0.4452	0.6328	0.5002	0.2319	0.3296	0.2605
	Multifamily	0.2951	0.4195	0.3316	0.1537	0.2185	0.1727
	Single-family	0.5113	0.7268	0.5746	0.2663	0.3785	0.2992
Heat Central Boiler	Manufactured	0.4958	0.7048	0.5571	0.2582	0.3670	0.2901
	Multifamily	0.3991	0.5674	0.4485	0.2079	0.2955	0.2336
	Single-family	0.5511	0.7834	0.6193	0.2870	0.4080	0.3225
Unknown Heat and Location ⁸⁰¹		n/a	n/a	n/a	0.5007	n/a	n/a

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁷⁹⁹ Assumes single zone. If not – adjust accordingly.

⁸⁰⁰ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

⁸⁰¹ 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_06152023.xls’ for calculation detail.

MEASURE CODE: RS-HVC-PROG-V05-240101

SUNSET DATE: 1/1/2030

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.⁸⁰² This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure are not 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 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 STAR⁸⁰³ qualified Advanced Thermostat⁸⁰⁴, 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 regard to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication⁸⁰⁵ 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,⁸⁰⁶ or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 44% programmable and 56% manual thermostats may

⁸⁰² 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.

⁸⁰³ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

⁸⁰⁴ Note Draft Specification v2.0 includes line-voltage advanced thermostats for the first time. These high voltage thermostats are used to control individual resistance heaters (such as baseboard units).

⁸⁰⁵ 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.

⁸⁰⁶ If the actual thermostat is a programmable and it is found to be used in override mode or otherwise effectively being operated like a manual thermostat, then the baseline may be considered to be a manual thermostat

be assumed.⁸⁰⁷

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years⁸⁰⁸ based upon equipment life only.⁸⁰⁹

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 should be used if available,⁸¹⁰ 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 \$75.⁸¹¹

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

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

$$\Delta kWh_{heat} = \%ElectricHeat * Elec_Heating_Consumption * \%Controlled * Heating_Reduction * HF * Eff_{ISR} + (\Delta Therms * F_e * 29.3)$$

$$\Delta kWh_{cool} = \%AC * ((EFLH_{cool} * Capacity_{cool} * 1/SEER2_{exist})/1,000) * \%Controlled * Cooling_Reduction * Eff_{ISR}$$

Where:

$\%ElectricHeat$ = Percentage of heating savings assumed to be electric

Heating Fuel	$\%ElectricHeat$
Controllable Electric Heat	100%

⁸⁰⁷ Value for blend of baseline thermostats comes from an IL Potential Study conducted by ComEd in 2013

⁸⁰⁸ Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

⁸⁰⁹ 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.

⁸¹⁰ Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.

⁸¹¹ ENERGY STAR models are currently being offered in the \$100-\$150 range. The assumed incremental cost is based on the middle of this range (\$125) 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
(i.e., ducted ASHP, GSHP, forced air electric furnace or baseboard heat)	
Natural Gas	0%
Unknown	7% ⁸¹²

Elec_Heating_Consumption

= Estimate of annual household heating consumption for electrically heated single-family homes.⁸¹³ If location and heating type is unknown, assume 11,407 kWh.⁸¹⁴

		Elec_Heating_Consumption (kWh) by Climate Zone (City based upon)		
Heating System ⁸¹⁵	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown
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
Electric Resistance (Forced Air Electric Furnace or baseboard)	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 home, assume 100%

= If single zone thermostat in multi zone home, assume 1 / # zones

= If line-voltage thermostat (controlling resistance heat), assume 1/#baseboard units

= If multi zone thermostat, assume 100%

= If unknown, assume 93%⁸¹⁶ for low voltage standard thermostats (controlling central systems), or 20% for line voltage thermostats controlling resistance heat in single family or 33% in multi family homes⁸¹⁷

Heating_Reduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat including accounting for Thermostat Optimization

⁸¹² Average (default) value of 7% electric ducted heat pump space heating from ResStock data for the state of 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.

⁸¹³ Based on Cadmus modeling performed for the 2011 Joint Assessment.

⁸¹⁴ 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".

⁸¹⁵ 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.

⁸¹⁶ 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 home's total consumption.

⁸¹⁷ Estimate based on a typical single family home having five baseboard units and a multi family home having three.

services⁸¹⁸

= If programs are evaluated during program deployment then custom savings assumptions should be applied. Otherwise use:

Existing Thermostat Type	Heating Reduction ⁸¹⁹
Manual	10.4%
Programmable	7.3%
Unknown (Blended)	8.5%

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

Household Type	HF
Single-Family	100%
Multifamily	65% ⁸²⁰
Actual	Custom ⁸²¹

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	90% ⁸²²

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%⁸²³

⁸¹⁸ Based on 2020 Guidehouse consumption data analysis in Illinois.

⁸¹⁹ 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). These values are adjusted upwards in v6 to account for inclusion of Thermostat Optimization savings in an estimated 45% of future participants (based on reported share of Nest and ecobee Illinois participants and 2020 rates of Thermostat Optimization). The basis for the Thermostat Optimization savings is Navigant "ComEd CY2018 Seasonal Savings Heating Season Impact Evaluation Report", March 2019. 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 Dunskey and Opinion Dynamics 2017 Baseline Study.

⁸²⁰ 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

⁸²¹ Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

⁸²² The 2020 Guidehouse evaluation in Illinois indicated that 6.75% of participants installed the advanced thermostat out of state. An additional reduction is applied to account for purchases that are never installed. Based on the available data this is estimated as an additional 3.25%.

⁸²³ 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

29.3 = kWh per therm

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

Thermostat control of air conditioning?	%AC
Yes	100%
No (including line voltage thermostats)	0%
Unknown	Actual population data, or 91% ⁸²⁴

EF_{LH}_{cool} = Estimate of annual household full load cooling hours for air conditioning equipment based on location and home type.

= Dependent on location: ⁸²⁵

Climate Zone (City based upon)	FLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	583	977	537	784	541	921
Zone 6 (Mason City)	291	489	268	392	271	461
Average/ unknown	514	861	472	690	477	811

Capacity_{cool} = Cooling output capacity of new equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)

= Actual installed – If actual size unknown, assume 36,000

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

= 12.6⁸²⁶

1/1000 = kBtu per Btu

Cooling_Reduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat including accounting for Thermostat Optimization:

= If programs are evaluated during program deployment then custom savings assumptions should be applied. Otherwise use:

= 8.4%⁸²⁷

(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.

⁸²⁴ 91% of homes have central cooling (based on NREL ResStock data for the state of Iowa).

⁸²⁵ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁸²⁶ Estimate of average SEER₂ efficiency of cooling equipment in homes receiving the thermostat. Based on average of 2015 and 2020 installed base value from Guidehouse, 2023 “EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case”.

⁸²⁷ 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

For example, an advanced thermostat replacing a programmable thermostat 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:

$$\begin{aligned}\Delta kWH &= \Delta kWH_{\text{heating}} + \Delta kWH_{\text{cooling}} \\ &= ((1 * 14,778 * 1 * 0.073 * 1 * 0.9) + (0 * 0.0314 * 29.3)) + (1 * ((489 * 36,000 * (1/12.6))/1,000) * 1 * 0.084 * 0.9) \\ &= 971 + 106 \\ &= 1,077 \text{ kWh}\end{aligned}$$

A line voltage advanced thermostat replacing a manual thermostat directly installed in a single-family home in Mason City with 5 baseboard resistance units:

$$\begin{aligned}\Delta kWH &= \Delta kWH_{\text{heating}} + \Delta kWH_{\text{cooling}} \\ &= ((1 * 17,703 * 1/5 * 0.104 * 1 * 1) + (0 * 0.0314 * 29.3)) + (0) \\ &= 368 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \%AC * (\%Controlled * Cooling_DemandReduction * Capacity_{cool} * (1/EER2))/1,000 * Eff_{ISR} * CF$$

Where:

Cooling_DemandReduction = Assumed average percentage reduction in total household cooling demand due to installation of advanced thermostat including accounting for Thermostat Optimization services
= 16.4%⁸²⁸

EER2 = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)
= Use actual EER2 rating where it is possible to measure or reasonably estimate. If EER2 unknown but SEER2 available convert using the equation:⁸²⁹

$$EER2 = (-0.02 * SEER2_{\text{exist}}^2) + (1.12 * SEER2_{\text{exist}})$$

If SEER2 or EER2 rating unavailable use 10.9⁸³⁰:

CF = Summer System Peak Coincidence Factor for Cooling
= 34%⁸³¹

heating fan or total annual household kWh. 8.4% is consistent with the Illinois TRM assumption and incorporates a statewide advanced thermostat evaluation utilizing participant AMI data. Further evaluation and regular review of this key assumption is encouraged.

⁸²⁸ The current Cooling_DemandReduction assumption is consistent with the Illinois TRM and incorporates a statewide advanced thermostat evaluation utilizing participant AMI data.

⁸²⁹ From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Master's Thesis, University of Colorado at Boulder.

⁸³⁰ Based on converting the SEER2 assumption to EER2.

⁸³¹ 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

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:

$$\begin{aligned}\Delta kW &= (1 * 1 * 0.164 * 36,000 * (1/10.9))/1,000 * 0.9 * 0.34 \\ &= 0.1657 \text{ kW}\end{aligned}$$

NATURAL GAS 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	93% ⁸³²

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume 562 therms.⁸³³

		Gas_Heating_Consumption (Therms) by Climate Zone (City based upon)		
Heating System	Building Type	Zone 5 (Burlington)	Zone 6 (Mason City)	Average/ unknown
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

cooling load, the impact during peak periods may be lower. This is an assumption that could use future evaluation to improve these estimates.

⁸³² Average (default) value of 75% gas space heating from NREL ResStock data for the state of 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.

⁸³³ Assumption that 93.4% of gas heated homes have furnaces and 6.6% have boilers, based on Dunskey and Opinion Dynamics Baseline Study results. 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".

For example, an advanced thermostat replacing a programmable thermostat directly-installed in a single zoned gas heated furnace single-family home in unknown location:

$$\begin{aligned}\Delta\text{Therms} &= 1.0 * 603 * 1 * 0.073 * 1 * 0.9 \\ &= 39.6 \text{ therms}\end{aligned}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

$$\begin{aligned}\Delta\text{Therms} &= \text{Therm impact calculated above} \\ \text{GCF} &= \text{Gas Coincidence Factor for Heating}^{834} \\ &= 0.014378 \text{ for Residential Boiler} \\ &= 0.016525 \text{ for Residential Space Heating (other)}\end{aligned}$$

For example, an advanced thermostat replacing a programmable thermostat directly-installed in a single zoned gas heated furnace single-family home in unknown location:

$$\begin{aligned}\Delta\text{Peak Therms} &= 39.6 * 0.016525 \\ &= 0.6544 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-ADTH-V09-260101

SUNSET DATE: 1/1/2029

⁸³⁴ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

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., ventilated attic with floor insulation, vented crawlspace, unheated garages) and semi-conditioned (defined as a space within the thermal envelope that is not intentionally heated for occupancy and is unventilated e.g. unfinished basement⁸³⁵). 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 or semi-conditioned areas that has been insulated.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing uninsulated or poorly insulated ductwork in unconditioned or semi-conditioned areas.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.⁸³⁶

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 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

⁸³⁵ Definition matches Regain factor discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012

⁸³⁶ Consistent with duct insulation measure life specified in the MidAmerican Energy Company Joint Assessment, February 2013.

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * TRF_{cool} * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $R_{existing}$ = Duct heat loss coefficient of existing duct [(hr-°F-ft²)/Btu]
 = Estimate of actual with minimum of 1.0 for uninsulated duct⁸³⁷
- R_{new} = Duct heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
 = Actual
- Area = Area of the duct surface exposed to the unconditioned space that has been insulated [ft²]. (e.g., for circular duct – Calculate the circumference of the duct (= π * diameter) multiplied by length (ft))
- TRF_{cool} = Thermal Regain Factor for cooling by space type. This accounts for the fact that not all cool air in semi-conditioned spaces is lost to the atmosphere and will provide useful conditioning⁸³⁸.
 = 1.0 for Unconditioned Spaces
 = 0.4 for Semi-Conditioned Spaces⁸³⁹
- $EFLH_{cooling}$ = Equivalent Full Load Cooling Hours
 = Dependent on location:⁸⁴⁰

Climate Zone (City based upon)	EFLH _{cool} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

- $\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 60°F duct supply air temperature⁸⁴¹

⁸³⁷ Based upon findings in ACEEE study of internal film resistance: L. Palmiter and E Kruse, Ecotope Inc, “True R-Values of Round Residential Ductwork.”

⁸³⁸ Definition of unconditioned areas is a space outside the thermal envelope (e.g., ventilated attic with floor insulation, vented crawlspace, unheated garages) and semi-conditioned (defined as a space within the thermal envelope that is not intentionally heated for occupancy and is unventilated e.g. unfinished basement).

⁸³⁹ Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

⁸⁴⁰ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁸⁴¹ Leaving coil air temperatures are typically about 55°F. 60°F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

Climate Zone (City based upon)	OA _{AVG,cooling} [°F] ⁸⁴²	ΔT _{AVG,cooling} [°F]
Zone 5 (Burlington)	77.8	17.8
Zone 6 (Mason City)	76.0	16.0
Average/Unknown	78.8	18.8

1,000 = Conversion from Btu to kWh

η_{cooling} = Seasonal energy efficiency ratio (SEER2) of cooling system (kWh/kWh)⁸⁴³
 = Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁸⁴⁴ If not available, use:⁸⁴⁵

Equipment Type	Age of Equipment	SEER2 Estimate of Sealed Duct	SEER2 Estimate of Unsealed Duct (SEER2*0.85)
Central AC	Before 2006	9.5	
	2006-2022	12.4	10.54
	2023 on	13.4	11.39
Heat Pump	Before 2006	9.5	8.1
	2006-2014	12.4	10.54
	2015-2022	13.3	11.3
	2023 on	14.3	12.16

For example, a single family house in Burlington with Central Air SEER2 = 12.4 and 10 ft. of uninsulated standard 6-inch round sealed duct in an unconditioned space.

$$\Delta \text{kWh}_{\text{cooling}} = ((1/1.0 - 1/(1.0 + 6)) * (\pi * 0.5 * 10) * 1 * 977 * 17.8) / (1,000 * 12.4)$$

$$= 18.9 \text{ kWh}$$

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:

$$\Delta \text{kWh}_{\text{heating}} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * \text{TRF}_{\text{Heat}} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(3,412 * \eta_{\text{heating}})}$$

Where:

⁸⁴² National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X

Climate.OneBuilding.Org. 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. See 'Ducts – OA Average_heating and cooling.xlsx' in 3.3.15 Duct Insulation analysis files for more details.

⁸⁴³ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

⁸⁴⁴ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

⁸⁴⁵ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

TRF_{Heat} = Thermal Regain Factor for heating by space type. This accounts for the fact that not all heat loss in semi-conditioned spaces is lost to the atmosphere and will provide useful conditioning⁸⁴⁶.

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces⁸⁴⁷

$EFLH_{heating}$ = Equivalent Full Load Heating Hours for ASHP

= Dependent on location⁸⁴⁸:

Climate Zone (City based upon)	EFLH _{Heating} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	1,991	1,618	2,104
Zone 6 (Mason City)	2,858	2,322	3,020
Average/ unknown	2,254	1,832	2,382

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 115°F duct supply temperature⁸⁴⁹

Climate Zone (City based upon)	OA _{AVG,heating} [°F] ⁸⁵⁰	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	40.2	74.8
Zone 6 (Mason City)	32.3	82.7
Average/Unknown	39.1	75.9

3,142 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system⁸⁵¹

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum

⁸⁴⁶ Definition of unconditioned areas is a space outside the thermal envelope (e.g., ventilated attic with floor insulation, vented crawlspace, unheated garages) and semi-conditioned (defined as a space within the thermal envelope that is not intentionally heated for occupancy and is unventilated e.g. unfinished basement).

⁸⁴⁷ Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

⁸⁴⁸ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁸⁴⁹ Forced air supply temperatures are typically 130°F. 115°F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

⁸⁵⁰ National Solar Radiation Data Base – 2007 - 2021 Update: Typical Meteorological Year X

Climate.OneBuilding.Org. 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. See 'Ducts – OA Average_heating and cooling.xlsx' in 3.3.15 Duct Insulation analysis files for more details.

⁸⁵¹ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

of 30 years) to account for degradation over time.⁸⁵² If not available, use:⁸⁵³

System Type	Age of Equipment	HSPF2 Estimate	nHeat (Effective COP Estimate) of Sealed Ducts (HSPF2/3.412)	ηHeat (Effective COP Estimate) of Unsealed Ducts (HSPF2/3.412)*0.85
Heat Pump	Before 2006	5.8	1.7	1.45
	2006–2014	6.5	1.91	1.62
	2015–2022	7	2.05	1.74
	2023 on	7.5	2.2	1.87

For example, a single family house in Burlington with a Heat Pump COP = 1.62 and 10 ft. of uninsulated standard 6-inch round sealed duct in an unconditioned space.

$$\Delta \text{kWh}_{\text{heating}} = ((1/1.0 - 1/(1.0 + 6)) * (\pi * 0.5 * 10) * 1 * 1,991 * 74.8) / (3,412 * 2.0)$$

$$= 293.8 \text{ kWh}$$

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.

$$\Delta \text{kWh}_{\text{heating}} = \Delta \text{Therms} * F_e * 29.3$$

Where:

- ΔTherms = Gas savings calculated with equation below.
- F_e = Percentage of heating energy consumed by fans, assume 3.14%⁸⁵⁴
- 29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta \text{kWh}_{\text{cooling}}}{\text{EFLH}_{\text{cooling}}} * CF$$

Where:

- EFLH_{cooling} = Equivalent Full Load Cooling Hours
- = Dependent on location:⁸⁵⁵

⁸⁵² Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes,” May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

⁸⁵³ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

⁸⁵⁴ 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 (E_f in MMBtu/yr) and E_{ae} (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.

⁸⁵⁵ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Climate Zone (City based upon)	EFLH _{cool} (Hours)		
	Single Family Existing	Multifamily Existing	Manufactured Existing
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

CF = Summer System Peak Coincidence Factor for Cooling
= 68% if central AC, 72% if ducted ASHP⁸⁵⁶

For example, using the above for a single family house in Burlington with Central Air SEER2 = 12.4 and 10 ft. of uninsulated standard 6-inch round sealed duct in an unconditioned space.

$$\Delta kW = 18.9 / 977 * 0.68$$

$$= 0.0132 \text{ kW}$$

NATURAL GAS SAVINGS

If homes with a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * TRF_{\text{Heat}} * EFLH_{\text{gasheat}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

R_{existing} = Duct heat loss coefficient with existing insulation
[(hr-°F-ft²)/Btu]

R_{new} = Duct heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]

Area = Area of the duct surface exposed to the unconditioned space that has been insulated [ft²].

$EFLH_{\text{gasheat}}$ = Equivalent Full load heating hours for Furnaces (see above)
= Dependent on location:⁸⁵⁷

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	901	1,038	628	882	765	1,062
Zone 6 (Mason City)	1,295	1,488	901	1,265	1,100	1,525
Average/ unknown	1,020	1,174	712	997	867	1,203

⁸⁵⁶ 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)'.

⁸⁵⁷ 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. In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values.

$\Delta T_{\text{AVG, heating}}$	= Average temperature difference [$^{\circ}\text{F}$] during heating season (see above)
100,000	= Conversion from BTUs to Therms
η_{heat}	= Efficiency of gas heating system
	= Actual ⁸⁵⁸ . If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ⁸⁵⁹ If not available, use 87% for sealed ducts ⁸⁶⁰ or 74% for unsealed ducts ⁸⁶¹

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.

$$\Delta \text{Therms} = ((1/1.0 - 1/(1.0 + 6)) * (\pi * 0.5 * 10) * 1 * 1,038 * 74.8) / (100,000 * 0.87)$$

$$= 12.0 \text{ Therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * \text{GCF}$$

Where:

ΔTherms	= Therm impact calculated above
GCF	= Gas Coincidence Factor for Heating ⁸⁶²
	= 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.

$$\Delta \text{PeakTherms} = 12.0 * 0.016525$$

$$= 0.198 \text{ Therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁸⁵⁸ 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.

⁸⁵⁹ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

⁸⁶⁰ 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.

⁸⁶¹ An 85% distribution efficiency is then applied to account for duct losses for furnaces.

⁸⁶² Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

MEASURE CODE: RS-HVC-DUCT-V07-260101

SUNSET DATE: 1/1/2029

2.4.20 Advanced Thermostat Optimization Services (Removed 2021)

This measure was removed in 2021. Optimization services are now offered for all customers by the main advanced thermostat manufacturers and the added benefit from these services has been added to the 2.4.18 Advanced Thermostat measure.

2.4.21 Gas-Fired Heat Pump

DESCRIPTION

A gas-fired heat pump (also commonly referred to a gas heat pump or GHP) is a type of heat pump whose primary input drive energy is natural gas, rather than an electrically driven compressor. Gas-fired heat pumps can be separated into two categories, work-activated technologies where a delivered fuel drives a prime mover (e.g., internal combustion engine) which supplies work to a refrigerant compressor, and heat-activated where the primary energy input to the heat pump cycle is thermal energy, often from fuel combustion, driving a sorption-type or other thermally-driven heat pump cycle. Gas heat pumps can typically be direct replacements or substitutes for conventional space heating boilers. Additionally, some are capable of providing cooling and/or domestic water heating.

This measure characterizes:

- a) Time of Sale:
 - ii. The installation of a residential sized (<300,000 Btuh/h), gas-fired heat pump in a residential location. This could relate to the replacement of an existing conventional boiler at the end of its useful life, or the installation of a new system in a new home.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed gas-fired heat pump 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

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 84%.⁸⁶³

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁸⁶⁴

DEEMED MEASURE COST

For space heating, the actual installed cost of the gas heat pump should be used minus the assumed installation cost of the baseline equipment. If unknown, assume (\$1,820 + \$4,260) for a new baseline 84% AFUE boiler.⁸⁶⁵

For combi installations, the full installation cost of a baseline water heater should be added to the above installation cost for space heating with baseline equipment. Defaults are provided below.

Water Heater Type	Baseline Installed Cost ⁸⁶⁶
Electric Resistance	\$905

⁸⁶³ Code of Federal Regulations for gas-fired hot water boilers manufactured on or after January 15, 2021 (10 CFR 432(e)(3))

⁸⁶⁴ U.S. Energy Information Administration | Assumptions to the Annual Energy Outlook 2026: Commercial Demand Module.

⁸⁶⁵ Boiler baseline and labor costs are interpolated from Updated Buildings Sector Appliance and Equipment Costs and Efficiencies by Guidehouse and Leidos, prepared for the U.S. Energy Information Administration, March 2023. Labor costs are presented after baseline costs so that they may be easily distinguished as needed. See "Res HVAC Cost Update 2026" for more details.

⁸⁶⁶ U.S. Energy Information Administration (EIA), Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, March 2023

Gas-Fired	\$1,215
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If actual cost of Gas Heat Pump Unknown, assume (\$3,199 + \$2,350) per ton.⁸⁶⁷

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

LOADSHAPE

Loadshape RG01 – Residential Boiler

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RG07 – Residential Water Heat (gas)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Gas-fired heat pumps consume electricity during their operation and therefore result in increased site electric load.

$$\Delta kWh = \frac{-Power * EFLH}{1,000}$$

Where:

Power = Nominal maximum electrical power requirement for the gas-fired heat pump, W
= Actual. If unknown, assume 0.0052 W per Btu/hr heating input capacity⁸⁶⁸

EFLH = Equivalent Full Load Hours for heating
= Dependent on location:⁸⁶⁹

Climate Zone (City Based Upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	754	869	526	738	641	890
Zone 6	1,084	1,246	755	1,059	921	1,277

⁸⁶⁷ U.S. Energy Information Administration (EIA), Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, March 2023. Labor costs have been calculated using the difference between retail and total installed costs and are presented as additive so that they can be distinguished as needed.

⁸⁶⁸ Based on average of power requirements for Robur K18 (0.004341794 W/Btu/hr) and GAHP-A (0.005960768 W/Btu/hr)

⁸⁶⁹ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Climate Zone (City Based Upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
(Mason City)						
Average/ Unknown	854	983	596	835	726	1,007

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Space Heating Savings

$$\Delta Therms_{SH} = \frac{EFLH * Capacity * \left(\frac{(AFUE_{eff} * (1 - Derating_{eff}))}{(AFUE_{base} * (1 - Derating_{base}))} - 1 \right)}{100,000}$$

Where:

EFLH = Equivalent Full Load Hours for heating

= Dependent on location:⁸⁷⁰

Climate Zone (City based upon)	EFLH (Hours)					
	Single Family New	Single Family Existing	Multifamily New	Multifamily Existing	Manufactured New	Manufactured Existing
Zone 5 (Burlington)	754	869	526	738	641	890
Zone 6 (Mason City)	1084	1246	755	1059	921	1277
Average/ unknown	854	983	596	835	726	1007

Capacity = Nominal heating input capacity (Btu/hr) for gas-fired heat pump

= Actual

AFUE_{base} = Baseline boiler Annual Fuel Utilization Efficiency (AFUE) rating

= 84%

AFUE_{eff} = Annual Fuel Utilization Efficiency (AFUE) rating of the gas-fired heat pump

⁸⁷⁰ 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). In 2024, the change to HDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

	= Actual. If unknown, 130% can be assumed ⁸⁷¹
Derating _{Eff}	= Derating of AFUE to account for units not operating in field at rated efficiency = 5.9% ⁸⁷²
Derating _{Base}	= Derating of AFUE to account for units not operating in field at rated efficiency = 3.3% ⁸⁷³

For example, for a 100,000 Btuh 133% AFUE gas-fired heat pump purchased and installed for existing home in unknown location:

$$\begin{aligned}\Delta \text{kWh} &= -0.0052 * 100,000 * 983 / 1,000 \\ &= -511.16 \text{ kWh} \\ \Delta \text{Therms}_{\text{SH}} &= (983 * 100,000 * ((1.33 * (1-0.059)) / (0.84 * (1-0.033)) - 1)) / 100,000 \\ &= 531.6 \text{ Therms}\end{aligned}$$

Domestic Hot Water Savings

$$\Delta \text{Therms}_{\text{DHW}} = \frac{(T_{\text{out}} - T_{\text{in}}) * \text{GPD} * \text{Household} * 365 * \gamma_{\text{Water}} * 1.0 * (\frac{1}{TE_{\text{base}}} - \frac{1}{COP_{\text{EE}}})}{100,000}$$

Where:

T _{out}	= Tank temperature = Actual; otherwise assume 126.5 ⁸⁷⁴
T _{in}	= Incoming water temperature from well or municipal systems = Actual; otherwise assume 57.8 ⁸⁷⁵
GPD	= Gallons per day of hot water use per person = 17.6 ⁸⁷⁶
Household	= Average number of people per household

⁸⁷¹ Based on findings presented Brio and GTI's Gas Heat Pump Roadmap Industry White Paper, November 2019.

⁸⁷² Based on findings from Massachusetts study; Cadmus "High Efficiency Heating Equipment Impact Evaluation," March 2015.

⁸⁷³ Ibid.

⁸⁷⁴ CPUC Residential Retrofit - High Impact Measure Evaluation Report Draft. Dec. 7, 2009. Pg 76. Average temperature setpoints for two utilities.

⁸⁷⁵ 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 TMYX data from all Class I stations located in Des Moines, IA. Des Moines represents the average of the state. See 'Hot Water – Temp to DHW Tank Calc.xlsx' in 2.3.1 Gas Water Heater analysis files for more details.

⁸⁷⁶ Deoreo, B., and P. Mayer. Residential End Uses of Water Study 2013 Update. Water Research Foundation, 2014.

Household Unit Type	Household
Manufactured	1.96 ⁸⁷⁷
Single-Family – Deemed	2.55 ⁸⁷⁸
Multifamily – Deemed	1.71 ⁸⁷⁹
Custom	Actual Occupancy or Number of Bedrooms ⁸⁸⁰

365 = Days per year

γ_{Water} = Specific weight capacity of water (lb/gal)

= 8.33 lbs/gal

1 = Specific heat of water (Btu/lbm/°F)

100,000 = Converts Btu to Therms

TE_{base} = Rated efficiency of baseline water heater (expressed as Uniform Energy Factor (UEF) or Thermal Efficiency as provided below).

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor ⁸⁸¹
Residential Electric Storage Water Heaters $\leq 75,000$ Btu/h	≤ 55 gallon tanks	Very small	UEF = $0.8808 - (0.0008 * \text{Rated Storage Volume in Gallons})$
		Low	UEF = $0.9254 - (0.0003 * \text{Rated Storage Volume in Gallons})$
		Medium	UEF = $0.9307 - (0.0002 * \text{Rated Storage Volume in Gallons})$
		High	UEF = $0.9349 - (0.0001 * \text{Rated Storage Volume in Gallons})$
	> 55 gallon and ≤ 120 gallon tanks ⁸⁸²	Very small	UEF = $1.9236 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		Low	UEF = $2.0440 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		Medium	UEF = $2.1171 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		High	UEF = $2.2418 - (0.0011 * \text{Rated Storage Volume in Gallons})$
Residential Electric Instantaneous Water Heaters	$\leq 12\text{kW}$ and ≤ 2 gal	All Other	UEF = 0.91
		High	UEF = 0.92
Residential Gas Storage Water Heaters $\leq 75,000$ Btu/h	≤ 55 gallon tanks	Very small	UEF = $0.3456 - (0.0020 * \text{Rated Storage Volume in Gallons})$
		Low	UEF = $0.5982 - (0.0019 * \text{Rated Storage Volume in Gallons})$
		Medium	UEF = $0.6483 - (0.0017 * \text{Rated Storage Volume in Gallons})$
		High	UEF = $0.6920 - (0.0013 * \text{Rated Storage Volume in Gallons})$
	> 55 gallon and ≤ 100 gallon tanks	Very small	UEF = $0.6470 - (0.0006 * \text{Rated Storage Volume in Gallons})$
		Low	UEF = $0.7689 - (0.0005 * \text{Rated Storage Volume in Gallons})$
		Medium	UEF = $0.7897 - (0.0004 * \text{Rated Storage Volume in Gallons})$
		High	UEF = $0.8072 - (0.0003 * \text{Rated Storage Volume in Gallons})$
Residential Gas Fired Instantaneous Water Heaters	< 2 gal and $> 50,000$ Btu/h	Very Small	UEF = 0.80
		All Other	UEF = 0.81

⁸⁷⁷ Average household size by building type and water heater fuel type based on the 2007 RASS.

⁸⁷⁸ NREL ResStock building characteristic data released in 2022.

⁸⁷⁹ Ibid

⁸⁸⁰ 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.

⁸⁸¹ All Residential sized Federal Standards are from DOE Standard 10 CFR 430, Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431

⁸⁸² It is assumed that tanks 55 gallons will not be eligible measures due to the high baseline.

Residential Oil Storage Water Heater	≤50 gallon tanks	Very small	UEF = 0.2509 – (0.0012 * Rated Storage Volume in Gallons)
		Low	UEF = 0.5330 – (0.0016 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.6087 – (0.0016 * Rated Storage Volume in Gallons)
		High	UEF = 0.6815 – (0.0014 * Rated Storage Volume in Gallons)

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:

Storage Water Heater Draw Pattern ⁸⁸³	
Draw Pattern	First Hour Rating (gallons)
Very Small	≥ 0 and < 18
Low	≥ 18 and < 51
Medium	≥ 51 and < 75
High	≥ 75

Instantaneous Water Heater Draw Pattern ⁸⁸⁴	
Draw Pattern	Max GPM
Very Small	≥ 0 and < 1.7
Low	≥ 1.7 and < 2.8
Medium	≥ 2.8 and < 4
High	≥ 4

COP_{EE} = Rated efficiency of the commercial gas heat pump as certified expressed as Uniform Energy Factor (UEF) or Coefficient of Performance.

= Actual

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

For example, A single family home is replacing the existing space heating and water heating baseline equipment with an 100,000 Btu/hr output gas heat pump system rated for a COP of 1.3. The baseline equipment being replaced is gas furnace and a gas-fired storage hot water heater. Baseline equipment efficiency: Gas-fired storage hot water heater – 0.78 TE for a high draw pattern and 80 gallon tank.

$$\Delta \text{Therms}_{\text{DHW}} = ((126.5 - 57.8) * 17.6 * 2.55 * 365 * 8.33 * 1.0 * (1/0.78 - 1/1.3))/100,000$$

$$= 48.1 \text{ Therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = (\Delta \text{Therms}_{\text{SH}} * \text{GCF}) + \left(\frac{\Delta \text{Therms}_{\text{DHW}}}{365} \right)$$

Where:

$\Delta \text{Therms}_{\text{SSH}}$ = Space Heating Therm impact calculated above

⁸⁸³ Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1, Table I—Draw Pattern To Be Used Based on First-Hour Rating.

⁸⁸⁴ Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1, Table II—Draw Pattern To Be Used Based on Maximum GPM Rating.

GCF = Gas Coincidence Factor for heating⁸⁸⁵

= 0.014378 for Residential Boiler

$\Delta\text{Therms}_{\text{DHW}}$ = Domestic Hot Water Therm impact calculated above

For example, for a 100,000 Btuh 133% AFUE gas-fired heat pump purchased and installed for existing home in unknown location:

$$\begin{aligned}\Delta\text{Therms} &= (531.7 * 0.014378) + (48.1/365) \\ &= 7.7766 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GFHP-V04-270101

SUNSET DATE: 1/1/2030

⁸⁸⁵ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.4.22 Boiler Reset Controls

DESCRIPTION

This measure relates to improving system efficiency by adding controls to residential heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. The water can be run a little cooler during fall and spring, and a little hotter during the coldest parts of the winter. A boiler reset control has two temperature sensors - one outside the house and one in the boiler water. As the outdoor temperature goes up and down, the control adjusts the water temperature setting to the lowest setting that is meeting the house heating demand. There are also limits in the controls to keep a boiler from operating outside of its safe performance range.⁸⁸⁶

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

DEFINITION OF EFFICIENT EQUIPMENT

Natural gas single family residential customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse fashion with outdoor air temperature. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer's recommended minimum return temperature. This boiler reset measure is limited to existing condensing boilers serving a single-family residence. Boiler reset controls for non-condensing boilers in single-family residences should be implemented as a custom measure, and the cost-effectiveness should be confirmed.

DEFINITION OF BASELINE EQUIPMENT

Existing condensing boiler in a single-family residential setting without boiler reset controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 15 years.⁸⁸⁷

DEEMED MEASURE COST

The cost of this measure is \$612.⁸⁸⁸

LOADSHAPE

N/A

Coincidence Factor

N/A

⁸⁸⁶ Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors, See 'Boiler Reset Control – NaturalGasEfficiency.org'.

⁸⁸⁷ DEER2014 EUL table

⁸⁸⁸ Nexant. Questar DSM Market Characterization Report. August 9, 2006.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \frac{\text{EFLH} * \text{Capacity} * \left(\frac{1}{\text{AFUE}} \right) * SF}{100,000}$$

Where:

EFLH = Equivalent Full Load Hours for heating

= Dependent on location⁸⁸⁹

Climate Zone (City Based Upon)	EFLH (Hours)	
	Single Family New	Single Family Existing
Zone 5 (Burlington)	754	869
Zone 6 (Mason City)	1,084	1,246
Average/Unknown	854	983

Capacity = Nominal heating input capacity boiler size (Btu/hr) for boiler that controls are being applied to

= Actual

AFUE = Existing Condensing Boiler Annual Fuel Utilization Efficiency Rating

= Actual; if unknown, default to 61.6%⁸⁹⁰

⁸⁸⁹ 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 unit's 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). Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁸⁹⁰ 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.

SF = Savings Factor, 5%⁸⁹¹

For example, boiler reset controls installed on an existing 50,000 btu/hr capacity boiler in a single-family home in Burlington would save:

$$\begin{aligned}\Delta\text{Therms} &= ((\text{EFLH} * \text{Capacity} * (1/\text{AFUE}) * \text{SF}) / 100,000 \\ &= ((869 * 50,000 * (1/0.616) * 0.05) / 100,000 \\ &= 35.3 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-BREC-V01-260101

SUNSET DATE: 1/1/2029

⁸⁹¹ Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. See 'Boiler Reset Control – NaturalGasEfficiency.org'. This savings value is also supported by Cadmus impact evaluation for the Electric and Gas Program Administrators of Massachusetts: Cadmus, Home Energy Services Impact Evaluation, August 2012.

2.5 Lighting

2.5.1 Compact Fluorescent Lamp – Standard (Removed 2021)

This measure was archived due to no utility currently offering the measure and an out of date savings characterization. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 1.0 Volume 3: Nonresidential Measures; Final: August 1, 2016; Effective January 1, 2017 in which the measure was last active.

2.5.2 Compact Fluorescent Lamp – Specialty (Removed 2021)

This measure was archived due to no utility currently offering the measure and an out of date savings characterization. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 1.0 Volume 3: Nonresidential Measures; Final: August 1, 2016; Effective January 1, 2017 in which the measure was last active.

2.5.3 LED Lamp – Standard

DESCRIPTION

NOTE: This characterization should now only be used for Low Income programs where it can be confirmed that the LED Lamp is replacing a halogen or incandescent bulb (for example a Direct Install Program).

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.

In December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that the more stringent standards (45 lumen per watt) prescribed in the 2007 EISA regulation to become effective in 2020 (known as the ‘Backstop’ provision), were not economically justified. However, in April 2022 DOE reversed this decision by issuing a Final rule for both the broadened General Service Lamp definition as well as the implementation of the 45 lumen per watt backstop. DOE stated that it will use its enforcement discretion to minimize impacts on the supply chain and effectively allow companies to continue the manufacture and import of noncompliant bulbs through the remainder of 2022, and allow retailers to continue selling them with limited enforcement until July 2023. Since only CFL and LEDs are able to meet this provision, and CFLs are now such a small part of the market – when enacted this effectively means the LED becomes baseline.

This measure is now limited to low income direct install programs, where we can be sure the LED is replacing inefficient lighting. The lifetime of this measure is reduced to represent the replacement of two incandescent/halogen bulbs.

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, new lamps must meet eligibility criteria as provided below⁸⁹²:

Efficiency Level	Lumens / watt	
	CRI<90	CRI≥90
Tier 1	80	70
CEE Tier 2 ⁸⁹³	95	80

Qualification could also be based on the Design Light Consortium’s qualified product list.⁸⁹⁴

⁸⁹² Note Tier 1 is consistent with v2.1 of the ENERGY STAR specification which has been sunset as of December 31, 2024.

⁸⁹³ Also required to have rated life of 25,000 hours and dimming capability.

⁸⁹⁴ <https://www.designlights.org/QPL>

DEFINITION OF BASELINE EQUIPMENT

For Direct Install programs use the actual wattage being replaced. Defaults provided should only be used when it is not possible to determine actual wattages.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The rated life of omnidirectional LED lamps is assumed to be 20,230.⁸⁹⁵ However, since only LED (or CFL) bulbs will be able to be purchased from July 2023, it is assumed that the LED will prevent use of two incandescent/halogen baseline bulbs, assuming that purchasers would have some bulbs in storage. Measure life for all measures should therefore be two years.

DEEMED MEASURE COST

For direct install, wherever possible, actual install costs should be used. If unavailable, assume the following lamp costs plus labor:⁸⁹⁶

CRI	Product Type	Cost
<90	Tier 1 LED	\$3.16
	CEE T2 LED	\$3.29
>=90	Tier 1 LED	\$3.67
	CEE T2 LED	\$3.75

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,⁸⁹⁷ CFL and LED by weightings provided in table below.⁸⁹⁸ 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.

Note for Direct Install – use the actual wattage of the lamp being replaced, if unknown assume defaults below.

⁸⁹⁵ Average rated life of omnidirectional bulbs on the ENERGY STAR qualified products list as of June 5, 2018.

⁸⁹⁶ Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017. The baseline cost reflects the baseline mix. See “2022 LED Measure Cost and O&M Calc.xls” for more information.

⁸⁹⁷ Incandescent/Halogen wattage is based upon the post first phase of EISA wattage.

⁸⁹⁸ Weightings based upon review of CREED LightTracker data for Illinois and DOE, 2019 ‘Energy Savings Forecast of Solid-State Lighting in General Illumination Applications’. See ‘Lighting Forecast Workbook_2022.xls’.

Iowa Energy Efficiency Statewide Technical Reference Manual—2.5.3 LED Lamp – Standard

Watts_{EE} = Actual wattage of LED purchased / installed – If unknown, use default provided below:⁸⁹⁹

Lower Lumen Range	Upper Lumen Range	Inc/ Halogen	CFL ⁹⁰⁰	LED ⁹⁰¹	Watts _{Base}	WattsEff TIER 1		WattsEff CEE T2		DeltaWatts TIER 1		DeltaWatts CEE T2	
		31%	1%	68%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90*	CRI >=90	CRI <90	CRI >=90
250	309	25	4.7	3.7	10.3	3.5	4.0	2.9	3.5	6.8	6.3	7.4	6.8
310	749	29	8.8	7.1	13.9	6.6	7.6	5.6	6.6	7.3	6.3	8.3	7.3
750	1,049	43	15.0	12.0	21.6	11.2	12.9	9.5	11.2	10.4	8.8	12.2	10.4
1,050	1,489	53	21.2	16.9	28.1	15.9	18.1	13.4	15.9	12.3	10.0	14.8	12.3
1,490	2,600	72	34.1	27.3	41.2	25.6	29.2	21.5	25.6	15.6	12.0	19.7	15.6
2,601	3,300	150	49.2	39.3	73.7	36.9	42.2	31.1	36.9	36.8	31.5	42.6	36.8
3,301	3,999	200	60.8	48.7	95.6	45.6	52.1	38.4	45.6	50.0	43.5	57.2	50.0
4,000	6,000	300	83.3	66.7	139.1	62.5	71.4	52.6	62.5	76.6	67.6	86.4	76.6
Weighted Average, if unknown ⁹⁰²					23.2	12.4				10.8			

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR and CRI<90.

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

Program	Discounted In Service Rate (ISR) ⁹⁰³
Direct Install ⁹⁰⁴	97%

Hours = Average hours of use per year

Installation Location	Hours
Residential Interior and in-unit Multifamily	1,088 ⁹⁰⁵
Exterior	2,475 ⁹⁰⁶
Unknown	1,157 ⁹⁰⁷

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).

⁸⁹⁹ Watts_{EE} are calculated using the midpoint of the lumen range and an efficacy of 80 lumens/watt for ESTAR CRI <90, 70 lumens/watt for ESTAR CRI >90, 95 lumens/watt for CEE Tier 2 CRI <90, 80 lumens/watt for CEE Tier 2 CRI >90,

⁹⁰⁰ Baseline CFL watts are calculated using the midpoint of the lumen range and an assumed efficacy of 60 lumens/watt.

⁹⁰¹ Baseline LED watts are calculated using the midpoint of the lumen range and an assumed efficacy of 75 lumens/watt.

⁹⁰² Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

⁹⁰³ 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.

⁹⁰⁴ Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys.

⁹⁰⁵ 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.

⁹⁰⁶ Based on secondary research conducted as part of the Illinois PY5/PY6 ComEd Residential Lighting Program evaluation.

⁹⁰⁷ Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.

$$= 1 - ((HF / \eta_{Heat}) * \%ElecHeat)$$

If unknown assume 0.93⁹⁰⁸

Where:

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

= 53% for interior or unknown location⁹⁰⁹

= 0% for exterior or unheated location

$\eta_{HeatElectric}$ = Efficiency in COP of Heating equipment

= Actual system efficiency including duct loss – If not available, use:⁹¹⁰

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (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	1.27 ⁹¹¹

$\%ElecHeat$ = Percentage of home with electric heat

Heating fuel	$\%ElecHeat$
Electric	100%
Fossil Fuel	0%
Unknown	17% ⁹¹²

$WHFe_{Cool}$ = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting.

Bulb Location	$WHFe_{Cool}$
Building with cooling	1.12 ⁹¹³
Building without cooling or exterior	1.0

⁹⁰⁸ Calculated using defaults; $1 - ((0.53/1.27) * 0.17) = 0.93$.

⁹⁰⁹ 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.

⁹¹⁰ 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.

⁹¹¹ 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.

⁹¹² Based on Dunsky and Opinion Dynamics Baseline Study results.

⁹¹³ 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. Master's Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

Bulb Location	WHFe _{Cool}
Unknown	1.11 ⁹¹⁴

For example, a 11W LED lamp, 900 lumens, CRI 85, is installed through Direct Install replacing a 40W halogen:

$$\Delta kWh = ((40 - 11) / 1,000) * 0.97 * 1,157 * (0.93 + (1.11 - 1))$$

$$= 33.8 \text{ kWh}$$

This value should be claimed for two years.

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	1.22 ⁹¹⁵
Building without cooling or exterior	1.0
Unknown	1.19 ⁹¹⁶

CF = Summer peak Coincidence Factor for measure.

Bulb Location	CF
Residential Interior and in-unit Multifamily ⁹¹⁷	13.1%
Exterior ⁹¹⁸	1.8%
Unknown ⁹¹⁹	12.5%

Other factors as defined above.

For example, for a 11W LED lamp, 900 lumens, installed through Direct Install replacing a 40W halogen:

$$\Delta kW = ((40 - 11) / 1,000) * 0.90 * 1.19 * 0.125$$

$$= 0.0039 \text{ kW}$$

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes:⁹²⁰

⁹¹⁴ 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 Dunskey and Opinion Dynamics Baseline Study results).

⁹¹⁵ 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.

⁹¹⁶ The value is estimated at 1.19 (calculated as $1 + (0.88 * 0.61 / 2.8)$).

⁹¹⁷ Based on analysis of loadshape data provided by Cadmus.

⁹¹⁸ Based on Itron eShapes lighting loadprofiles.

⁹¹⁹ Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.

⁹²⁰ Negative value because this is an increase in heating consumption due to the efficient lighting.

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

Where:

HF	= Heating Factor or percentage of light savings that must now be heated = 53% for interior or unknown location ⁹²¹ = 0% for exterior or unheated location
0.03412	= Converts kWh to Therms
$\eta_{HeatGas}$	= Efficiency of heating system = 74% ⁹²²
%GasHeat	= Percentage of homes with gas heat

Heating Fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83% ⁹²³

For example, for a 11W LED lamp, 900 lumens installed through Direct Install replacing a 40W halogen:

$$\begin{aligned}\Delta Therms &= - (((40 - 11) / 1,000) * 0.90 * 1,157 * 0.53 * 0.03412) / 0.74 * 0.83 \\ &= - 0.61 \text{ therms}\end{aligned}$$

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:

$\Delta Therms$	= Therm impact calculated above
HeatDays	= Heat season days per year = 215 ⁹²⁴

⁹²¹ 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.

⁹²² 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: $((0.60 * 0.92) + (0.40 * 0.8)) * (1 - 0.15) = 0.74$.

⁹²³ Based on Dunsky and Opinion Dynamics Baseline Study results

⁹²⁴ Calculated number of days where HDD 60 > 0. NCDC US Climate Hourly Normals 15-year data set (2006-2020) for Des Moines. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

For example, for a 11W LED lamp, installed through Direct Install replacing a 40W halogen:

$$\begin{aligned}\Delta\text{PeakTherms} &= -0.61 / 215 \\ &= -0.0028 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-LTG-LEDA-V12-270101

SUNSET DATE: 1/1/2029

2.5.4 LED Lamp – Specialty

DESCRIPTION

NOTE: This characterization should now only be used for Low Income programs where it can be confirmed that the LED Lamp is replacing a halogen or incandescent bulb (for example a Direct Install Program).

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 would become 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 9/5/2019 DOE repealed the 2017 Final rule, preventing this expansion of the definition of General Service Lamp to include these lamps. However, in April 2022 DOE reversed this decision by issuing a Final rule for both the broadened General Service Lamp definition as well as the implementation of the 45 lumen per watt backstop. DOE stated that it will use its enforcement discretion to minimize impacts on the supply chain and effectively allow companies to continue the manufacture and import of noncompliant bulbs through the remainder of 2022, and allow retailers to continue selling them with limited enforcement until July 2023. Since only CFL and LEDs are able to meet this provision, and CFLs are now such a small part of the market – when enacted this effectively means the LED becomes baseline.

The measure is now limited to low income direct install programs where we can be sure the LED is replacing inefficient lighting. The lifetime of this measure however is reduced to represent the replacement of two incandescent/halogen bulbs.

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, new lamps must meet eligibility criteria as provided below⁹²⁵:

Efficiency Level	Lamp Type	Lumens / watt	
		CRI<90	CRI≥90
Tier 1	Directional	70	61
	Decorative / Globe	65	65
CEE Tier 2 ⁹²⁶	Directional	85	70
	Decorative / Globe	95	80

Qualification could also be based on the Design Light Consortium's qualified product list.⁹²⁷

⁹²⁵ Note Tier 1 is consistent with v2.1 of the ENERGY STAR specification which has been sunset as of December 31, 2024.

⁹²⁶ Also required to have dimming capability.

⁹²⁷ <https://www.designlights.org/QPL>.

DEFINITION OF BASELINE EQUIPMENT

For Direct Install programs use the actual wattage being replaced. Defaults provided should only be used when it is not possible to determine actual wattages.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The rated life for directional bulbs is assumed to be 25,042 and for decorative bulbs, 17,129 hours.⁹²⁸ However, since only LED (or CFL) bulbs will be able to be purchased from July 2023, it is assumed that the LED will prevent use of two incandescent/halogen baseline bulbs, assuming that purchasers would have some bulbs in storage. Measure life for all measures should therefore be two years.

DEEMED MEASURE COST

Wherever possible, actual install costs should be used. If unavailable assume the following lamps costs, plus labor:⁹²⁹

Bulb Type	CRI	Product Type	Cost
Directional	<90	Tier 1 LED	\$7.80
		CEE T2 LED	\$18.96
	>=90	Tier 1 LED	\$7.63
		CEE T2 LED	\$18.54
Decorative	<90	Tier 1 LED	\$7.50
		CEE T2 LED	\$7.83
	>=90	Tier 1 LED	\$8.69
		CEE T2 LED	\$9.08

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,⁹³⁰ CFL and LED by weightings provided in table below.⁹³¹ Note that when an IA net-to-gross

⁹²⁸ Average rated life of directional and decorative bulbs on the ENERGY STAR qualified products list as of April, 2020.

⁹²⁹ Lamp costs are based upon WECC review of bulbs purchased through the Alliant program January – April 2017. The baseline cost reflects the baseline mix. See “2022 LED Measure Cost and O&M Calc.xls” for more information.

⁹³⁰ Incandescent/Halogen wattage is based upon the ENERGY STAR specification for lamps and the Energy Policy and Conservation Act of 2012.

⁹³¹ Weightings based on review of CREED LightTracker data and DOE, 2019 ‘Energy Savings Forecast of Solid-State Lighting in General Illumination Applications’. See ‘Lighting Forecast Workbook_2022.xls’.

(NTG) factor is determined for this measure, this blended baseline should be replaced with the Incandescent/Halogen baseline only.

Note for Direct Install – use the actual wattage of the lamp being replaced, if unknown assume defaults below.

Watts_{EE} = Actual wattage of LED purchased / installed. If unknown, use default provided below:⁹³²

⁹³² 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.”

Iowa Energy Efficiency Statewide Technical Reference Manual—2.5.4 LED Lamp – Specialty

EISA exempt bulb types:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/ Hal	Baseline LED	WattsBase	WattsEff TIER 1		WattsEff CEE T2		DeltaWatts TIER 1		DeltaWatts CEE T2	
				27%	73%		CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90*	CRI >=90	CRI <90	CRI >=90
EISA Exempt	3-Way ⁹³³	250	449	25	5.0	10.3	4.4	5.0	3.7	4.4	5.9	5.3	6.6	5.9
		450	799	40	8.9	17.2	7.8	8.9	6.6	7.8	9.4	8.2	10.6	9.4
		800	1,099	60	13.6	25.9	11.9	13.6	10.0	11.9	14.0	12.3	15.9	14.0
		1,100	1,599	75	19.3	34.1	16.9	19.3	14.2	16.9	17.2	14.8	19.8	17.2
		1,600	1,999	100	25.7	45.4	22.5	25.7	18.9	22.5	22.9	19.7	26.5	22.9
		2,000	2,549	125	32.5	57.0	28.4	32.5	23.9	28.4	28.6	24.5	33.1	28.6
		2,550	2,999	150	39.6	68.9	34.7	39.6	29.2	34.7	34.2	29.3	39.7	34.2
	Globe (medium and intermediate base < 750 lumens)	90	179	10	2.4	4.4	2.1	2.1	1.4	1.7	2.4	2.4	3.0	2.8
		180	249	15	3.9	6.8	3.3	3.3	2.3	2.7	3.5	3.5	4.6	4.2
		250	349	25	5.4	10.6	4.6	4.6	3.2	3.7	6.0	6.0	7.5	6.9
		350	749	40	10.0	17.9	8.5	8.5	5.8	6.9	9.5	9.5	12.2	11.1
	Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10	1.4	3.7	1.2	1.2	0.8	1.0	2.5	2.5	2.9	2.7
		90	149	15	2.2	5.6	1.8	1.8	1.3	1.5	3.7	3.7	4.3	4.1
		150	299	25	4.1	9.6	3.5	3.5	2.4	2.8	6.2	6.2	7.3	6.8
		300	749	40	9.5	17.6	8.1	8.1	5.5	6.6	9.5	9.5	12.1	11.1
	Globe (candelabra bases less than 1,050 lumens)	90	179	10	2.4	4.4	2.1	2.1	1.4	1.7	2.4	2.4	3.0	2.8
		180	249	15	3.9	6.8	3.3	3.3	2.3	2.7	3.5	3.5	4.6	4.2
		250	349	25	5.4	10.6	4.6	4.6	3.2	3.7	6.0	6.0	7.5	6.9
		350	499	40	7.7	16.3	6.5	6.5	4.5	5.3	9.7	9.7	11.8	11.0
		500	1,049	60	14.1	26.3	11.9	11.9	8.2	9.7	14.3	14.3	18.1	16.6
	Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1,050 lumens)	70	89	10	1.4	3.7	1.2	1.2	0.8	1.0	2.5	2.5	2.9	2.7
		90	149	15	2.2	5.6	1.8	1.8	1.3	1.5	3.7	3.7	4.3	4.1
		150	299	25	4.1	9.6	3.5	3.5	2.4	2.8	6.2	6.2	7.3	6.8
		300	499	40	7.3	15.9	6.1	6.1	4.2	5.0	9.8	9.8	11.7	11.0
		500	1,049	60	14.1	26.3	11.9	11.9	8.2	9.7	14.3	14.3	18.1	16.6
Weighted Average, if unknown ⁹³⁴						20.7	9.4				11.3			

⁹³³ For 3-way bulbs or fixtures, the product's median lumens value will be used to determine both LED and baseline wattages.

⁹³⁴ Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

Iowa Energy Efficiency Statewide Technical Reference Manual—2.5.4 LED Lamp – Specialty

*If lumen range is known but Efficiency rating or CRI is unknown assume and CRI<90.

Directional Lamps – For Directional R, BR, and ER lamp types:⁹³⁵

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Baseline LED	Watts _{Base}	WattsEff TIER 1		WattsEff CEE T2		DeltaWatts TIER 1		DeltaWatts CEE T2	
				5%	95%		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	7.4	9.1	6.4	7.3	5.2	6.4	2.8	1.8	3.9	2.8
		473	524	45	8.3	10.2	7.1	8.2	5.9	7.1	3.1	2.1	4.4	3.1
		525	714	50	10.3	12.4	8.9	10.2	7.3	8.9	3.5	2.2	5.1	3.5
		715	937	65	13.8	16.4	11.8	13.5	9.7	11.8	4.6	2.9	6.7	4.6
		938	1,259	75	18.3	21.3	15.7	18.0	12.9	15.7	5.6	3.3	8.3	5.6
		1,260	1,399	90	22.2	25.7	19.0	21.8	15.6	19.0	6.7	3.9	10.1	6.7
		1,400	1,739	100	26.2	30.0	22.4	25.7	18.5	22.4	7.6	4.3	11.5	7.6
		1,740	2,174	120	32.6	37.2	28.0	32.1	23.0	28.0	9.2	5.1	14.2	9.2
		2,175	2,624	150	40.0	45.7	34.3	39.3	28.2	34.3	11.5	6.4	17.5	11.5
		2,625	2,999	175	46.9	53.6	40.2	46.1	33.1	40.2	13.4	7.5	20.5	13.4
		3,000	4,500	200	62.5	69.7	53.6	61.5	44.1	53.6	16.1	8.2	25.6	16.1
	*R, BR, and ER with medium screw bases w/ diameter ≤2.25"	400	449	40	7.1	8.8	6.1	7.0	5.0	6.1	2.7	1.8	3.8	2.7
		450	499	45	7.9	9.8	6.8	7.8	5.6	6.8	3.1	2.1	4.3	3.1
		500	649	50	9.6	11.7	8.2	9.4	6.8	8.2	3.5	2.3	4.9	3.5
		650	1,199	65	15.4	18.0	13.2	15.2	10.9	13.2	4.8	2.8	7.1	4.8
	*ER30, BR30, BR40, or ER40	400	449	40	7.1	8.8	6.1	7.0	5.0	6.1	2.7	1.8	3.8	2.7
		450	499	45	7.9	9.8	6.8	7.8	5.6	6.8	3.1	2.1	4.3	3.1
		500	649	50	9.6	11.7	8.2	9.4	6.8	8.2	3.5	2.3	4.9	3.5
	*BR30, BR40, or ER40	650	1,419	65	17.2	19.7	14.8	17.0	12.2	14.8	5.0	2.8	7.6	5.0
	*R20	400	449	40	7.1	8.8	6.1	7.0	5.0	6.1	2.7	1.8	3.8	2.7
		450	719	45	9.7	11.6	8.4	9.6	6.9	8.4	3.2	2.0	4.7	3.2
	*All reflector	200	299	20	4.2	5.0	3.6	4.1	2.9	3.6	1.4	0.9	2.1	1.4

⁹³⁵ From pg. 13 of the Energy Star Specification for lamps v2.1.

Iowa Energy Efficiency Statewide Technical Reference Manual—2.5.4 LED Lamp – Specialty

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Baseline LED	Watts _{Base}	WattsEff TIER 1		WattsEff CEE T2		DeltaWatts TIER 1		DeltaWatts CEE T2	
				5%	95%		CRI <90	CRI ≥90	CRI <90	CRI ≥90	CRI <90*	CRI ≥90	CRI <90	CRI ≥90
	lamps below lumen ranges specified above	300	399	30	58	7.1	5.0	5.7	4.1	5.0	2.1	1.4	3.0	2.1
Weighted Average, if unknown ⁹³⁶						16.7	12.2				4.5			

*If lumen range is known but Efficiency rating or CRI is unknown assume and CRI<90. Directional lamps are exempt from first phase of EISA regulations.

EISA non-exempt bulb types:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/ Hal	Watt ^{SEE} LED	Watts Base	WattsEff TIER 1		WattsEff CEE T2		DeltaWatts TIER 1		DeltaWatts CEE T2	
				32%	68%		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	10.4	3.5	4.0	2.9	3.5	6.9	6.4	7.4	6.9
		310	749	29	9.6	14.8	6.6	7.6	5.6	6.6	8.1	7.2	9.2	8.1
		750	1049	43	16.4	23.4	11.2	12.9	9.5	11.2	12.2	10.6	14.0	12.2
		1050	1489	53	23.1	31.0	15.9	18.1	13.4	15.9	15.1	12.9	17.7	15.1
		1490	2600	72	37.2	46.4	25.6	29.2	21.5	25.6	20.9	17.2	24.9	20.9
Weighted Average, if unknown ⁹³⁷						25.3	12.4				12.9			

*If lumen range is known but Efficiency rating or CRI is unknown assume and CRI<90.

⁹³⁶ Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

⁹³⁷ Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

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

Program	Discounted In Service Rate (ISR) ⁹³⁸
Direct Install ⁹³⁹	97%

Hours = Average hours of use per year

Installation Location	Hours
Residential Interior and in-unit Multifamily	763 ⁹⁴⁰
Exterior	2,475 ⁹⁴¹
Unknown	1,020 ⁹⁴²

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).

$$= 1 - ((HF / \eta_{Heat}) * \%ElecHeat)$$

If unknown assume 0.93⁹⁴³

Where:

HF = Heating Factor or percentage of light savings that must now be heated
 = 53% for interior or unknown location⁹⁴⁴
 = 0% for exterior or unheated location

$\eta_{HeatElectric}$ = Efficiency in COP of Heating equipment
 = Actual system efficiency including duct loss – If not available, use:⁹⁴⁵

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 – 2014	7.7	1.92

⁹³⁸ 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.

⁹³⁹ Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys.

⁹⁴⁰ 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.

⁹⁴¹ Based on secondary research conducted as part of the Illinois PY5/PY6 ComEd Residential Lighting Program evaluation.

⁹⁴² 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.

⁹⁴³ Calculated using defaults: $1 - ((0.53/1.27) * 0.17) = 0.93$

⁹⁴⁴ 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.

⁹⁴⁵ 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	η_{Heat} (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	1.27 ⁹⁴⁶

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	17% ⁹⁴⁷

WHFeCool = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting.

Bulb Location	WHFeCool
Building with cooling	1.12 ⁹⁴⁸
Building without cooling or exterior	1.0
Unknown	1.11 ⁹⁴⁹

For example, for a 5W LED lamp, 200 lumens, 85 CRI decorative LED bulb is installed through direct install replacing a 25W incandescent:

$$\begin{aligned}\Delta \text{kWh} &= ((25 - 5) / 1,000) * 0.90 * 1,020 * (0.93 + (1.11 - 1)) \\ &= 19.1 \text{ kWh}\end{aligned}$$

This value should be claimed for two years.

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.

⁹⁴⁶ 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.

⁹⁴⁷ Based on Dunsky and Opinion Dynamics Baseline Study results.

⁹⁴⁸ 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. Master's Thesis, University of Colorado at Boulder), converted to $COP = EER / 3.412 = 2.8COP$).

⁹⁴⁹ 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).

Bulb Location	WHFdCool
Building with cooling	1.22 ⁹⁵⁰
Building without cooling or exterior	1.0
Unknown (e.g., Retail, Upstream, and Efficiency Kits)	1.19 ⁹⁵¹

CF = Summer Peak Coincidence Factor for measure.

Bulb Location	CF
Residential Interior and in-unit Multifamily ⁹⁵²	13.1%
Exterior ⁹⁵³	1.8%
Unknown ⁹⁵⁴	11.4%

Other factors as defined above

For example, for a 5W LED lamp, 200 lumens, decorative LED bulb is installed through direct install replacing a 25W incandescent:

$$\begin{aligned}\Delta kW &= ((25 - 5) / 1,000) * 0.90 * 1.19 * 0.114 \\ &= 0.0024 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

Heating Penalty for Natural Gas heated homes:⁹⁵⁵

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

Where:

HF = Heating Factor or percentage of light savings that must be heated
 = 53% for interior or unknown location⁹⁵⁶
 = 0% for exterior or unheated location

0.03412 = Converts kWh to Therms

$\eta_{HeatGas}$ = Efficiency of heating system
 = 74%⁹⁵⁷

⁹⁵⁰ 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.

⁹⁵¹ The value is estimated at 1.19 (calculated as $1 + (0.88 * 0.61 / 2.8)$).

⁹⁵² Based on analysis of loadshape data provided by Cadmus.

⁹⁵³ Based on Itron eShapes lighting loadprofiles.

⁹⁵⁴ 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.

⁹⁵⁵ Negative value because this is an increase in heating consumption due to the efficient lighting.

⁹⁵⁶ 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.

⁹⁵⁷ 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

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83% ⁹⁵⁸

For example, for a 5W LED lamp, 200 lumens, decorative LED bulb is installed through direct install replacing a 25W incandescent:

$$\begin{aligned}\Delta\text{Therms} &= - (((25 - 5) / 1,000) * 0.90 * 1,020 * 0.53 * 0.03412) / 0.74) * 0.83 \\ &= - 0.372 \text{ therms}\end{aligned}$$

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:

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year

$$= 215^{959}$$

For example, for a 5W LED lamp, 200 lumens, decorative LED bulb is installed through direct install replacing a 25W incandescent:

$$\begin{aligned}\Delta\text{PeakTherms} &= -0.372 / 215 \\ &= -0.0017 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-LTG-LEDS-V11-270101

SUNSET DATE: 1/1/2029

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: $((0.60 * 0.92) + (0.40 * 0.8)) * (1 - 0.15) = 0.74$.

⁹⁵⁸ Based on Dunskey and Opinion Dynamics Baseline Study results

⁹⁵⁹ Calculated number of days where HDD 60 > 0. NCDC US Climate Hourly Normals 15-year data set (2006-2020) for Des Moines.

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.⁹⁶⁰ 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.⁹⁶¹

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.⁹⁶²

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 \$49.⁹⁶³

LOADSHAPE

Loadshape E01 – Flat

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS⁹⁶⁴

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

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following:

⁹⁶⁰ ENERGY STAR “Save Energy, Money and Prevent Pollution with LED Exit Signs”

⁹⁶¹ 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.

⁹⁶² GDA Associates Inc. “Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures,” June 2007.

⁹⁶³ 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.

⁹⁶⁴ 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 ⁹⁶⁵	Incandescent (dual sided)	40W ⁹⁶⁶
	Incandescent (single sided)	20W
	CFL (dual sided)	14W ⁹⁶⁷
	CFL (single sided)	7W

Watts_{EE} = Actual wattage if known, if unknown assume singled sided 2W and dual sided 4W⁹⁶⁸

Hours = Annual operating hours
= 8760

WHF_{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).

$$= 1 - ((HF / \eta_{Heat}) * \%ElecHeat)$$

If unknown, assume 0.93⁹⁶⁹

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

= 53%⁹⁷⁰ for interior or unknown location

= 0% for exterior or unheated location

η_{Heat} = Efficiency in COP of Heating equipment

= Actual system efficiency including duct loss – If not available, use:⁹⁷¹

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (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	1.27 ⁹⁷²

$\%ElecHeat$ = Percentage of home with electric heat

⁹⁶⁵ 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.

⁹⁶⁶ Average incandescent watts are assumed at 40W as listed by the U.S. Department of Energy, ENERGY STARY Life Cycle Cost Exit-Sign Calculator.

⁹⁶⁷ Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

⁹⁶⁸ Average Exit LED watts are assumed as a 2W as listed in Appendix B 2013-14 Table of Standard Fixture Wattages.

⁹⁶⁸ Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

⁹⁶⁹ Calculated using defaults; $1 - ((0.53/1.27) * 0.17) = 0.93$

⁹⁷⁰ 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.

⁹⁷¹ 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.

⁹⁷² 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.

Heating Fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	17% ⁹⁷³

WHFeCool = Waste Heat Factor for energy to account for cooling savings from reducing waste heat from efficient lighting.

Bulb Location	WHFeCool
Building with cooling	1.12 ⁹⁷⁴
Building without cooling or exterior	1.0
Unknown	1.11 ⁹⁷⁵

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

$$\begin{aligned}\Delta kWh &= ((14 - 4) / 1,000) * 8760 * (0.58 + (1.12 - 1)) \\ &= 61.3 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS⁹⁷⁶

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * WHFdCool * CF$$

Where:

WHFdCool = Waste Heat Factor for demand to account for cooling savings from efficient lighting

Bulb Location	WHFdCool
Building with cooling	1.22 ⁹⁷⁷
Building without cooling or exterior	1.0
Unknown	1.19 ⁹⁷⁸

CF = Summer peak Coincidence Factor for this measure

$$= 100\%⁹⁷⁹$$

⁹⁷³ Based on Dunskey and Opinion Dynamics Baseline Study results.

⁹⁷⁴ 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. Master's Thesis, University of Colorado at Boulder), converted to $COP = EER / 3.412 = 2.8COP$).

⁹⁷⁵ 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 Dunskey and Opinion Dynamics Baseline Study results).

⁹⁷⁶ 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).

⁹⁷⁷ 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.

⁹⁷⁸ The value is estimated at 1.19 (calculated as $1 + (0.88 * 0.61 / 2.8)$).

⁹⁷⁹ Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in a building with cooling:

$$\begin{aligned}\Delta kW &= ((14 - 4) / 1,000) * 1.22 * 1.0 \\ &= 0.0122 \text{ kW}\end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Heating Penalty for Natural Gas heated homes:⁹⁸⁰

$$\Delta Therms = - \frac{\frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * HF * 0.03412}{\eta_{HeatGas}} * \%GasHeat$$

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 53% for interior or unknown location⁹⁸¹

= 0% for exterior or unheated location

0.03412 = Converts kWh to Therms

$\eta_{HeatGas}$ = Efficiency of heating system

= 74%⁹⁸²

%GasHeat = Percentage of homes with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	83% ⁹⁸³

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in gas heated building:

$$\begin{aligned}\Delta Therms &= - (((14 - 4) / 1,000) * 8,766 * 0.53 * 0.03412) / 0.74 * 1.0 \\ &= - 2.1 \text{ therms}\end{aligned}$$

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:

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

⁹⁸⁰ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁹⁸¹ 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.

⁹⁸² 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: $((0.60 * 0.92) + (0.40 * 0.8)) * (1 - 0.15) = 0.74$.

⁹⁸³ Based on Dunsky and Opinion Dynamics Baseline Study results.

Where:

Δ Therms = Therm impact calculated above
 HeatDays = Heat season days per year
 = 215⁹⁸⁴

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in gas heated building:

Δ PeakTherms = -2.1/215
 = -0.0098 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 Install ⁹⁸⁵	CFL lamp	\$13.00 ⁹⁸⁶	0.57 years ⁹⁸⁷
	Incandescent lamp	\$11.27 ⁹⁸⁸	0.17 years ⁹⁸⁹

MEASURE CODE: RS-LTG-EXIT-V04-240101

SUNSET DATE: 1/1/2028

⁹⁸⁴ Calculated number of days where HDD 60 >0. NCDC US Climate Hourly Normals 15-year data set (2006-2020) for Des Moines. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

⁹⁸⁵ If program component is unknown use 70/30 split for costs and life = \$11.87 and 0.29 yrs

⁹⁸⁶ Consistent with assumption as listed by the U.S. Department of Energy, ENERGY STAR Life Cycle Cost Exit-Sign Calculator 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).

⁹⁸⁷ 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.

⁹⁸⁸ Assume incandescent A-lamp 45W is \$1.27 per Itron, Ex Ante Measure cost Study, 2014 "WA017_MCS Results Matrix - Volume I (1).xlsx"

⁹⁸⁹ 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 1500/8760.

2.5.6 LED Fixtures (Removed 2026)

This measure was archived due to utilities no longer offering the measure. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 9 Volume 2: Residential Measures; Final: July 31, 2024; Effective January 1, 2025 in which the measure was last active.

2.5.7 LED Holiday Lights (Removed 2027)

This measure was archived due to utilities no longer offering the measure. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 10 Volume 2: Residential Measures; Final: July 31, 2025; Effective January 1, 2026 in which the measure was last active.

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.⁹⁹⁰ 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 20 years.⁹⁹¹

DEEMED MEASURE COST

The actual capital cost for this measure should be used.

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

⁹⁹⁰ Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.

⁹⁹¹ As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

Algorithm

CALCULATION OF SAVINGS**ELECTRIC ENERGY SAVINGS**Test In / Test Out Approach

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

Where:

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to air sealing

$$= \frac{\left(\frac{CFM50_{pre} - CFM50_{post}}{N_{cool}} \right) * 60 * 24 * CDD * DUA * 0.018 * LM}{(1,000 * \eta_{Cool})}$$

$CFM50_{pre}$ = Infiltration at 50 Pascals as measured by blower door before air sealing
= Actual⁹⁹²

$CFM50_{post}$ = 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:⁹⁹³

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	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 location⁹⁹⁴:

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616

⁹⁹² 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.

⁹⁹³ 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, *Exegesis 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.

⁹⁹⁴ National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

Climate Zone (City based upon)	CDD 65
Average/ unknown	1,068

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75⁹⁹⁵

0.018 = Specific Heat Capacity of Air (Btu/ft³*°F)

1000 = Converts Btu to kBtu

η_{Cool} = Efficiency (SEER2) of Air Conditioning equipment (kBtu/kWh)⁹⁹⁶

= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.⁹⁹⁷ If unknown, assume the following:⁹⁹⁸

Age of Equipment	SEER2 Sealed Ducts Estimate	SEER2 Unsealed Ducts Estimate (SEER Sealed * 0.85)
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015-2022	12.4	10.5
Heat Pump 2015-2022	13.3	11.3
Central AC after 1/1/2023	13.4	11.4
Heat Pump after 1/1/2023	14.3	12.2

LM = Latent multiplier to account for latent cooling demand

= dependent on location:⁹⁹⁹

Climate Zone (City based upon)	LM
Zone 5 (Burlington)	4.1
Zone 6 (Mason City)	4.2
Average/ unknown	4.2

Heat_elec = Flag variable dependent on heating system fuel type

⁹⁹⁵ This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

⁹⁹⁶ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

⁹⁹⁷ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013," May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

⁹⁹⁸ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

⁹⁹⁹ 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.

= 1 if electric heating system

= 0 if gas furnace

$\Delta kWh_{elec_heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \frac{(CFM50_{Pre} - CFM50_{Post}) * 60 * 24 * HDD * 0.018}{N_{heat} * (\eta_{HeatElec} * 3,412)}$$

N_{heat} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on location and building height:¹⁰⁰⁰

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	22.2	19.7	18.0	16.0

HDD = Heating Degree Days

= Dependent on location:¹⁰⁰¹

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

$\eta_{HeatElec}$ = Efficiency of electric heating system¹⁰⁰²

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ¹⁰⁰³ If not available refer to default table below:¹⁰⁰⁴

¹⁰⁰⁰ 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, *Exegesis 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.

¹⁰⁰¹ 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.

¹⁰⁰² If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹⁰⁰³ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰⁰⁴ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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	HSPF2 Estimate	η Heat (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015-2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2
Resistance	N/A	N/A	1.00	1.00

3412 = Converts Btu to kWh

For example, for a 2-story single family home in unknown location with 9.8 SEER2 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:

$$\begin{aligned}
 \Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + ((\Delta \text{kWh}_{\text{elec_heating}} * \text{Heat}_{\text{elec}}) + (\Delta \text{kWh}_{\text{gas_heating}} * (1 - \text{Heat}_{\text{elec}}))) \\
 &= [(((3,400 - 2,250) / 27.9) * 60 * 24 * 1,068 * 0.75 * 0.018 * 4.2) / (1,000 * 9.8)] + \\
 &\quad [(((3,400 - 2,250) / 18.0) * 60 * 24 * 5052 * 0.018) / (1.92 * 3,412)) * 1] + [0 * (1 - 1)] \\
 &= 366.8 + 1277.1 \\
 &= 1,643.8 \text{ kWh}
 \end{aligned}$$

Conservative Deemed Approach

$$\Delta \text{kWh} = \text{SavingsPerUnit} * \text{SqFt}$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment¹⁰⁰⁵

Building Type	HVAC System	SavingsPerUnit (kWh/ft ²)
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

¹⁰⁰⁵ 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.

Building Type	HVAC System	SavingsPerUnit (kWh/ft²)
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

$\Delta kWh_{gas_heating}$ = If gas *furnace* heat, kWh savings for reduction in fan run time
= $\Delta Therms * F_e * 29.3$

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
= 3.14%¹⁰⁰⁶

29.3 = kWh per therm

For example, for a 2-story single family home in unknown location 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):

$$\Delta kWh_{gas_heating} = 114 * 0.0314 * 29.3$$

$$= 105 \text{ kWh}$$

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:¹⁰⁰⁷

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

¹⁰⁰⁶ 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 (E_f in MMBtu/yr) and E_{ae} (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.

¹⁰⁰⁷ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

CF = Summer System Peak Coincidence Factor for Cooling
 = 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹⁰⁰⁸
 43.1% for ductless HP used as supplemental or limited zone¹⁰⁰⁹

For example, for a 2-story single family home in unknown location with 9.8 SEER2 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:

$$\Delta kW = 541.4 / 861 * 0.68$$

$$= 0.43 \text{ kW}$$

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

$$\Delta Therms = \frac{\frac{(CFM50_{pre} - CFM50_{post})}{N_{heat}} * 60 * 24 * HDD * 0.018}{(\eta_{HeatGas} * 100,000)}$$

Where:

N_{heat} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions
 = Based on location and building height:¹⁰¹⁰

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	22.2	19.7	18.0	16.0

HDD = Heating Degree Days
 = Dependent on location:¹⁰¹¹

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

η_{HeatGas} = Efficiency of gas heating system

¹⁰⁰⁸ 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)'.

¹⁰⁰⁹ Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

¹⁰¹⁰ 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, *Exegesis 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.

¹⁰¹¹ 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.

= Equipment efficiency * distribution efficiency

= Actual¹⁰¹². If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ¹⁰¹³ If not available, use 74% for unsealed ducts¹⁰¹⁴ or 87% for sealed ducts

Other factors as defined above.

For example, for 2-story single family home in unknown location with a gas furnace with system efficiency of 70%, with pre- and post-sealing blower door test results of 3,400 and 2,250:

$$\Delta \text{Therms} = ((3,400 - 2,250) / 18.0) * 60 * 24 * 5,052 * 0.018 / (0.74 * 100,000)$$

$$= 113.1 \text{ therms}$$

Conservative Deemed Approach

$$\Delta \text{Therms} = \text{SavingsPerUnit} * \text{SqFt}$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment¹⁰¹⁵

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 conditioned square footage

= Actual

¹⁰¹² 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: (See: "BPI, Distribution Efficiency Table) or by performing duct blaster testing.

¹⁰¹³ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013," May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰¹⁴ This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant space heating system is a central warm-air furnace, and energy source of natural gas (based on Energy Information Administration, 2019 Residential Energy Consumption Survey, HC6.9 for the Midwest)). 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: $((0.60 * 0.92) + (0.40 * 0.8)) * (1 - 0.15) = 0.74$.

¹⁰¹⁵ 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.

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹⁰¹⁶

= 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:

$$\Delta PeakTherms = 113.1 * 0.016525$$

$$= 1.87 \text{ therms}$$

Conservative Deemed Approach

Building Type	HVAC System	SavingsPerUnit (Peak Therms/ft ²)
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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AIRS-V07-260101

SUNSET DATE: 1/1/2029

¹⁰¹⁶ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

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 to evaluate 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 20 years.¹⁰¹⁷

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

Where

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) * A_{attic} * (1 - FramingFactor_{Attic}) * CDD * 24 * DUA}{(1,000 * \eta_{Cool})}$$

R_{Attic} = R-value of new attic assembly including all layers between conditioned space and unconditioned space (ft²·°F·h/Btu)

¹⁰¹⁷ As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

- R_{old} = Actual¹⁰¹⁸
- R_{old} = R-value value of existing assembly and any existing insulation
(Minimum of R-5 for uninsulated assemblies)¹⁰¹⁹
- A_{Attic} = Total area of insulated ceiling/attic (ft²)
- $FramingFactor_{Attic}$ = Adjustment to account for area of framing
= Actual, or if unknown 7%¹⁰²⁰
- CDD = Cooling Degree Days
= Dependent on location:¹⁰²¹

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown	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)
= 0.75¹⁰²²
- 1000 = Converts Btu to kWh
- η_{Cool} = Seasonal Energy Efficiency Ratio 2 (SEER2) of cooling system (kBtu/kWh)¹⁰²³
= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time¹⁰²⁴, or if unknown, assume the following:¹⁰²⁵

¹⁰¹⁸ 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.

¹⁰¹⁹ 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).

¹⁰²⁰ ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

¹⁰²¹ National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

¹⁰²² This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

¹⁰²³ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

¹⁰²⁴ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes," May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013," May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰²⁵ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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	η Cool Sealed Duct Estimate	η Cool Unsealed Duct Estimate (η Cool Sealed * 0.85)
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015-2022	12.4	10.5
Heat Pump 2015-2022	13.3	11.3
Central AC after 1/1/2023	13.4	11.4
Heat Pump after 1/1/2023	14.3	12.2

Heat_elec = Flag variable dependent on heating system fuel type

= 1 if electric heating system

= 0 if gas furnace

kWh_elec_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) * A_{Attic} * (1 - FramingFactor_{Attic}) * HDD * 24}{(\eta_{HeatElec} * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:¹⁰²⁶

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

η HeatElec = Efficiency of electric heating system¹⁰²⁷

= Actual (where new or where it is possible to measure or reasonably estimate, assuming a heat pump distribution efficiency of 85% if equipment efficiency is available). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time¹⁰²⁸, or if not available, refer to default table below:¹⁰²⁹

¹⁰²⁶ 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.

¹⁰²⁷ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹⁰²⁸ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013," May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰²⁹ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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	HSPF2 Estimate	η Heat (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015-2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2
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 ft² of R-5 attic insulated to R-49, 9.8 SEER2 Central AC, and 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}
 \Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + ((\Delta \text{kWh}_{\text{elec_heating}} * \text{Heat_elec}) + (\Delta \text{kWh}_{\text{gas_heating}} * (1 - \text{Heat_elec}))) \\
 &= (((1/5 - 1/49) * 700 * (1 - 0.07) * 616 * 24 * 0.75) / (1,000 * 9.8)) + (((1/5 - 1/49) * 700 * (1 - 0.07) * 6,391 * 24) / (1.62 * 3,412)) * 1 + (0 * (1 - 1)) \\
 &= 132 + 3244 \\
 &= 3376 \text{ kWh}
 \end{aligned}$$

$\Delta \text{kWh}_{\text{gas_heating}}$ = If gas furnace heat, kWh savings for reduction in fan run time

$$= \Delta \text{Therms} * F_e * 29.3$$

Where:

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

$$= 3.14\%^{1030}$$

29.3 = kWh per therm

For example, for a single family home in Mason City with 700 ft² 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:

$$\begin{aligned}
 \Delta \text{kWh}_{\text{gas_heating}} &= 179.2 * 0.0314 * 29.3 \\
 &= 165 \text{ kWh}
 \end{aligned}$$

¹⁰³⁰ 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 (E_f in MMBtu/yr) and E_{ae} (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:¹⁰³¹

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹⁰³² 43.1% for ductless HP used as supplemental or limited zone¹⁰³³

For example, for a single family home in Mason City with 700 ft² of R-5 attic insulated to R-49, 9.8 SEER Central AC, and 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}\Delta kW &= 132 / 489 * 0.68 \\ &= 0.1836 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS Δ Therms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{attic}}\right) * A_{Attic} * (1 - FramingFactor_{Attic}) * HDD * 24}{(\eta_{HeatGas} * 100,000)}$$

Where:

HDD = Heating Degree Days

= Dependent on location:¹⁰³⁴

Climate Zone (City based upon)	HDD 60
--------------------------------	--------

¹⁰³¹ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹⁰³² 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)'.

¹⁰³³ Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

¹⁰³⁴ 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.

Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

η_{HeatGas} = Efficiency of gas heating system
= Equipment efficiency * distribution efficiency
= Actual (where new or where it is possible to measure or reasonably estimate, assuming heat pump 85% distribution efficiency if only equipment efficiency is available).¹⁰³⁵ If using rated efficiencies, derate efficiency by 1% per year (maximum of 30 years) to account for degradation over time¹⁰³⁶, or if not available, assume 74% for unsealed ducts¹⁰³⁷ 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 ft² of R-5 attic insulated to R-49, with a gas furnace with system efficiency of 74% with sealed ducts:

$$\Delta \text{Therms} = ((1/5 - 1/49) * 700 * (1 - 0.07) * 6,391 * 24) / (0.74 * 100,000)$$

$$= 242.3 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * GCF$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹⁰³⁸
= 0.014378 for Residential Boiler
= 0.016525 for Residential Space Heating (other)

¹⁰³⁵ 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: (See: "BPI, Distribution Efficiency Table) or by performing duct blaster testing.

¹⁰³⁶ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

¹⁰³⁷ This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant space heating system is a central warm-air furnace, and energy source of natural gas (based on Energy Information Administration, 2019 Residential Energy Consumption Survey, HC6.9 for the Midwest)). 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.

¹⁰³⁸ 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 700 ft² of R-5 attic insulated to R-49, with a gas furnace with system efficiency of 74% with sealed ducts:

$$\begin{aligned}\Delta\text{PeakTherms} &= 242.3 * 0.016525 \\ &= 4.005 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-AINS-V08-260101

SUNSET DATE: 1/1/2029

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 does not 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 20 years.¹⁰³⁹

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

Where

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to insulation

¹⁰³⁹ As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Rim}} \right) * A_{Rim} * (1 - FramingFactor_{Rim}) * CDD * 24 * DUA}{(1,000 * \eta_{Cool})}$$

R_{Rim} = R-value of new rim/band joist assembly including all layers between inside air and outside air (ft²·°F·h/Btu)

= Actual¹⁰⁴⁰

R_{Old} = R-value value of existing assembly and any existing insulation (ft²·°F·h/Btu).

(Minimum of R-5 for uninsulated assemblies)¹⁰⁴¹

A_{Rim} = Net area of insulated rim/band joist (ft²)

$FramingFactor_{Rim}$ = Adjustment to account for area of framing

=Actual, or if unknown 5%¹⁰⁴²

CDD = Cooling Degree Days

= Dependent on location and whether in conditioned or unconditioned space:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space
	CDD 65 ¹⁰⁴³	CDD 75 ¹⁰⁴⁴
Zone 5 (Burlington)	1,209	411
Zone 6 (Mason City)	616	264
Average/ unknown	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 ¹⁰⁴⁵

1000 = Converts Btu to kBtu

¹⁰⁴⁰ 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.

¹⁰⁴¹ 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).

¹⁰⁴² Assumes the average framing factor for joists running from front-to-back (0.094) and from side-to-side (0). The front-to-back FF was calculated based on 1.5" joists for every 16" (1.5"/16" = 0.094). The side-to-side FF is 0 since joists are continuous and uninterrupted.

¹⁰⁴³ National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

¹⁰⁴⁴ 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. 75°F for cooling and 50°F for heating are used based on professional judgment. Five year average cooling degree days with 75°F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72°F.

¹⁰⁴⁵ This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research," p31.

η_{Cool} = Seasonal Energy Efficiency Ratio 2 (SEER2) of cooling system (kBtu/kWh)¹⁰⁴⁶
 = Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹⁰⁴⁷ If unknown, assume the following:¹⁰⁴⁸

Age of Equipment	η_{Cool} Sealed Duct Estimate	η_{Cool} Unsealed Duct Estimate (η_{Cool} Sealed * 0.85)
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015-2022	12.4	10.5
Heat Pump 2015-2022	13.3	11.3
Central AC after 1/1/2023	13.4	11.4
Heat Pump after 1/1/2023	14.3	12.2

Heat_elec = Flag variable dependent on heating system fuel type
 = 1 if electric heating system
 = 0 if gas furnace

kWh_elec_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}} \right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJRim}{(\eta_{HeatElec} * 3412)}$$

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 ¹⁰⁴⁹	HDD 50 ¹⁰⁵⁰
Zone 5 (Burlington)	4,496	2,678
Zone 6 (Mason City)	6,391	4,222
Average/ unknown	5,052	3,126

¹⁰⁴⁶ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

¹⁰⁴⁷ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰⁴⁸ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

¹⁰⁴⁹ 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.

¹⁰⁵⁰ 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

η_{HeatElec} = Efficiency of electric heating system¹⁰⁵¹

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹⁰⁵² If not available, refer to default table below:¹⁰⁵³

System Type	Age of Equipment	HSPF2 Estimate	η_{Heat} (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	n_{Heat} (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015 - 2022	7	1.74	2.05
	2023 on	7.5	1.87	2.2
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%¹⁰⁵⁴

temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75°F for cooling and 50°F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

¹⁰⁵¹ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹⁰⁵² Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰⁵³ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

¹⁰⁵⁴ Consistent with ADJ_{Wall} ; 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, for a single family home in Mason City with 100 ft² of uninsulated (assume R-5) rim/band joist cavities in an unconditioned basement that is insulated to R-13. The home has 9.8 SEER2 Central AC and 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}\Delta kWh &= \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_elec) + (\Delta kWh_{gas_heating} * (1 - \\ &Heat_elec))) \\ &= (((1/5 - 1/13) * 100 * (1-0.25) * 264 * 24 * 0.75) / (1,000 * 9.8)) + (((1/5 - 1/13) * 100 * (1- \\ &0.25) * 4,222 * 24 * 0.63) / (1.62 * 3,412)) * 1) + (0 * (1 - 1)) \\ &= 4.5 + 106.6 \\ &= 111.1 kWh\end{aligned}$$

$$\begin{aligned}\Delta kWh_{gas_heating} &= \text{If gas } furnace \text{ heat, kWh savings for reduction in fan run time} \\ &= \Delta Therms * F_e * 29.3\end{aligned}$$

Where:

$$\begin{aligned}F_e &= \text{Furnace Fan energy consumption as a percentage of annual fuel} \\ &\text{consumption} \\ &= 3.14\%^{1055} \\ 29.3 &= \text{kWh per therm}\end{aligned}$$

For example, for a single family home in Mason City with 100 ft² 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:

$$\begin{aligned}\Delta kWh_{gas_heating} &= 8.0 * 0.0314 * 29.3 \\ &= 7.4 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$$\begin{aligned}FLH_{cooling} &= \text{Full load hours of air conditioning} \\ &= \text{Dependent on location:}^{1056}\end{aligned}$$

¹⁰⁵⁵ 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 (E_f in MMBtu/yr) and E_{ae} (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.

¹⁰⁵⁶ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

CF = Summer System Peak Coincidence Factor for Cooling
 = 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹⁰⁵⁷ 43.1% for ductless HP used as supplemental or limited zone¹⁰⁵⁸

For example, for a single family home in Mason City with 100 ft² of uninsulated (assume R-5) rim/band joist cavities in an unconditioned basement that is insulated to R-13. The home has 9.8 SEER2 Central AC and 1.91 (1.62 including distribution losses) COP heat pump:

$$\Delta kW = 4.5 / 489 * 0.68$$

$$= 0.0063 \text{ kW}$$

NATURAL GAS SAVINGS

Δ Therms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}} \right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJRim}{(\eta_{HeatGas} * 100,000)}$$

Where:

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 ¹⁰⁵⁹	HDD 50 ¹⁰⁶⁰
Zone 5 (Burlington)	4,496	2,678
Zone 6 (Mason City)	6,391	4,222
Average/ unknown	5,052	3,126

$\eta_{HeatGas}$ = Efficiency of gas heating system
 = Equipment efficiency * distribution efficiency

¹⁰⁵⁷ 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)'.

¹⁰⁵⁸ Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

¹⁰⁵⁹ 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.

¹⁰⁶⁰ 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. 75°F for cooling and 50°F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

= Actual.¹⁰⁶¹ If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹⁰⁶² If unknown, assume 74% for unsealed ducts¹⁰⁶³ 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 100 ft² 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:

$$\Delta \text{Therms} = ((1/5 - 1/13) * 100 * (1-0.25) * 4,222 * 24 * 0.63) / (0.87 * 100,000)$$

$$= 6.8 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹⁰⁶⁴

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, for a single family home in Mason City with 100 ft² 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:

$$\Delta \text{PeakTherms} = 6.8 * 0.016525$$

$$= 0.11 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

¹⁰⁶¹ 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: (See: "BPI, Distribution Efficiency Table") or by performing duct blaster testing.

¹⁰⁶² Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013," May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

¹⁰⁶³ This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant space heating system is a central warm-air furnace, and energy source of natural gas (based on Energy Information Administration, 2019 Residential Energy Consumption Survey, HC6.9 for the Midwest)). 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.

¹⁰⁶⁴ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-RINS-V08-260101

SUNSET DATE: 1/1/2029

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 20 years.¹⁰⁶⁵

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

Where

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{wall}}\right) * A_{wall} * (1 - FramingFactor_{wall}) * CDD * 24 * DUA}{(1,000 * \eta_{Cool})}$$

R_{wall} = R-value of new wall assembly including all layers between conditioned space and

¹⁰⁶⁵ As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

outside air ($\text{ft}^2 \cdot ^\circ\text{F} \cdot \text{h} / \text{Btu}$)

R_{old} = R-value value of existing assembly and any existing insulation ($\text{ft}^2 \cdot ^\circ\text{F} \cdot \text{h} / \text{Btu}$)
(Minimum of R-5 for uninsulated assemblies)¹⁰⁶⁶

A_{wall} = Net area of insulated wall (ft^2)

$\text{FramingFactor}_{\text{wall}}$ = Adjustment to account for area of framing
= Actual, or if unknown 25%¹⁰⁶⁷

CDD = Cooling Degree Days
= Dependent on location:¹⁰⁶⁸

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown	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)
= 0.75¹⁰⁶⁹

1000 = Converts Btu to kWh

η_{Cool} = Seasonal Energy Efficiency Ratio 2 (SEER2) of cooling system (kBtu/kWh)¹⁰⁷⁰
= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹⁰⁷¹ – If unknown, assume the following:¹⁰⁷²

Age of Equipment	η_{Cool} Sealed Duct Estimate	η_{Cool} Unsealed Duct Estimate (η_{Cool} Sealed * 0.85)
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015-2022	12.4	10.5

¹⁰⁶⁶ 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).

¹⁰⁶⁷ ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.

¹⁰⁶⁸ National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

¹⁰⁶⁹ 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.

¹⁰⁷⁰ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

¹⁰⁷¹ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰⁷² These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

Heat Pump 2015-2022	13.3	11.3
Central AC after 1/1/2023	13.4	11.4
Heat Pump after 1/1/2023	14.3	12.2

Heat_elec = Flag variable dependent on heating system fuel type
 = 1 if electric heating system
 = 0 if gas furnace

ΔkWh_elec_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{wall}}\right) * A_{wall} * (1 - FramingFactor_{wall}) * HDD * 24 * ADJWall}{(\eta_{HeatElec} * 3,412)}$$

HDD = Heating Degree Days
 = Dependent on location:¹⁰⁷³

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

ηHeatElec = Efficiency of electric heating system¹⁰⁷⁴
 = Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ¹⁰⁷⁵ If not available, refer to default table below:¹⁰⁷⁶

System Type	Age of Equipment	HSPF2 Estimate	ηHeat (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015 - 2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2
Resistance	N/A	N/A	1.00	1.00

¹⁰⁷³ 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.

¹⁰⁷⁴ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹⁰⁷⁵ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰⁷⁶ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

3412 = Converts Btu to kWh

ADJ_{wall} = Adjustment for wall insulation to account for prescriptive engineering algorithms consistently overclaiming savings
= 63%¹⁰⁷⁷

For example, for a single family home in Mason City with 990 ft² of R-5 walls insulated to R-13, 9.8 SEER2 Central AC, and 1.91 (1.62 including distribution losses) COP heat pump with sealed ducts:

$$\begin{aligned}\Delta kWh &= \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec}))) \\ &= (((1/5 - 1/13) * 990 * (1-0.25) * 616 * 24 * 0.75) / (1,000 * 9.8)) + (((1/5 - 1/13) * 990 * (1-0.25) * 6,391 * 24 * 0.63) / (1.62 * 3412)) * 1) + (0 * (1 - 1)) \\ &= 103 + 1598 \\ &= 1701 kWh\end{aligned}$$

$\Delta kWh_{gas_heating}$ = 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%¹⁰⁷⁸

29.3 = kWh per therm

For example, for a single family home in Mason City with 990 ft² 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:

$$\begin{aligned}\Delta kWh_{gas_heating} &= 119.3 * 0.0314 * 29.3 \\ &= 110 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLH_{cooling} = Full load hours of air conditioning

¹⁰⁷⁷ 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.

¹⁰⁷⁸ 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 (E_f in MMBtu/yr) and E_{ae} (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.

= Dependent on location:¹⁰⁷⁹

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

CF = Summer System Peak Coincidence Factor for Cooling

= 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹⁰⁸⁰ 43.1% for ductless HP used as supplemental or limited zone¹⁰⁸¹

For example, for a single family home in Mason City with 990 ft² of R-5 walls insulated to R-13, 9.8 SEER2 Central AC, and 1.91 (1.62 including distribution losses) COP heat pump with sealed ducts:

$$\begin{aligned}\Delta kW &= 103 / 489 * 0.68 \\ &= 0.1432 \text{ kW}\end{aligned}$$

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:¹⁰⁸²

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

ηHeatGas = Efficiency of gas heating system

= Equipment efficiency * distribution efficiency

= Actual¹⁰⁸³. If using rated efficiencies, derate efficiency value by 1% per year (maximum

¹⁰⁷⁹ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹⁰⁸⁰ 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)'.

¹⁰⁸¹ Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

¹⁰⁸² 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.

¹⁰⁸³ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit or performing a steady state

of 30 years) to account for degradation over time.¹⁰⁸⁴ If unknown, assume 74% for unsealed ducts¹⁰⁸⁵ 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 ft² of R-5 walls insulated to R-13, with a gas furnace with system efficiency of 87% with sealed ducts:

$$\Delta \text{Therms} = ((1/5 - 1/13) * 990 * (1 - 0.25) * 6,391 * 24 * 0.63) / (0.74 * 100,000)$$

$$= 101.5 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹⁰⁸⁶

= 0.014378 for Residential Boiler

= 0.016525 for Residential Space Heating (other)

For example, for a single family home in Mason City with 990 ft² of R-5 walls insulated to R-13, with a gas furnace with system efficiency of 87% and sealed ducts:

$$\Delta \text{PeakTherms} = 101.5 * 0.016525$$

$$= 1.7 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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: (See: "BPI, Distribution Efficiency Table") or by performing duct blaster testing.

¹⁰⁸⁴ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

¹⁰⁸⁵ This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant space heating system is a central warm-air furnace, and energy source of natural gas (based on Energy Information Administration, 2019 Residential Energy Consumption Survey, HC6.9 for the Midwest)). 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.

¹⁰⁸⁶ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

MEASURE CODE: RS-SHL-WINS-V07-260101

SUNSET DATE: 1/1/2029

2.6.5 Insulated Doors

DESCRIPTION

Doors constructed with better insulating materials can significantly improve a home's thermal envelope, by slowing the rate of energy loss to the outdoors. Energy and demand savings 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 door 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.¹⁰⁸⁷

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

Algorithm

CALCULATION OF 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.

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling_g} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * CDD * 24 * DUA}{(1,000 * \eta_{cooling})}$$

¹⁰⁸⁷ Fannie Mae Estimated useful life tables for multifamily properties.

Where:

$R_{existing}$ = Existing door heat loss coefficient $[(hr \cdot ^\circ F \cdot ft^2)/Btu]$. If unknown, assume 3.125¹⁰⁸⁸

R_{new} = New door heat loss coefficient $[(hr \cdot ^\circ F \cdot ft^2)/Btu]$

Area = Area of the door surface in square feet

CDD = Cooling Degree Days

= Dependent on location:¹⁰⁸⁹

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown	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)

= 0.75¹⁰⁹⁰

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio 2 (SEER2) of cooling system (kBtu/kWh)¹⁰⁹¹

= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹⁰⁹² If unknown, assume the following:¹⁰⁹³

Age of Equipment	η_{Cool} Estimate Sealed Duct Estimate	η_{Cool} Unsealed Duct Estimate (η_{Cool} Sealed * 0.85)
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015 - 2022	12.4	10.5
Heat Pump 2015 - 2022	13.3	11.3
Central AC after 1/1/2023	13.4	11.4
Heat Pump after 1/1/2023	14.3	12.2

Heat_elec = Flag variable dependent on heating system fuel type

¹⁰⁸⁸ IECC 2012 and 2015 requirements (U-value of at least 0.32, which equals an R-value of 3.125)

¹⁰⁸⁹ National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

¹⁰⁹⁰ 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.

¹⁰⁹¹ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

¹⁰⁹² Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰⁹³ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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 means that using the minimum standard is appropriate.

= 1 if electric heating system

= 0 if gas furnace

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:

$$\Delta \text{kWh}_{\text{elec_heating}} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * \text{HDD} * 24}{(3,412 * \eta_{\text{heatingElec}})}$$

Where:

HDD = Heating Degree Days

= Dependent on location:¹⁰⁹⁴

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

$\eta_{\text{heatingElec}}$ = Efficiency of electric heating system¹⁰⁹⁵

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ¹⁰⁹⁶ If not available, refer to default table below:¹⁰⁹⁷

System Type	Age of Equipment	HSPF2 Estimate	η_{Heat} (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	n_{Heat} (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015 - 2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2
Resistance	N/A	N/A	1.00	1.00

3,142 = Conversion from Btu to kWh.

¹⁰⁹⁴ 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.

¹⁰⁹⁵ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹⁰⁹⁶ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹⁰⁹⁷ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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 single family home in Mason City installing a new 21 ft² insulated door with an R-value of 11, savings with a 9.8 SEER2 central AC system and a 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}\Delta\text{kWh} &= \Delta\text{kWh}_{\text{cooling}} + ((\Delta\text{kWh}_{\text{elec_heating}} * \text{Heat_elec}) + (\Delta\text{kWh}_{\text{gas_heating}} * (1 - \text{Heat_elec}))) \\ &= (((1/3.125 - 1/11) * 21 * 616 * 24 * 0.75) / (1,000 * 9.8)) + (((1/3.125 - 1/11) * 21 * 6,391 * 24) / (3,412 * 1.62)) * 1 + (0 * (1 - 1)) \\ &= 5.4 \text{ kWh} + 133.5 \text{ kWh} \\ &= 138.9 \text{ kWh}\end{aligned}$$

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.

$$\Delta\text{kWh}_{\text{gas_heating}} = \Delta\text{Therms} * F_e * 29.3$$

Where:

- ΔTherms = Gas savings calculated with equation below
- F_e = Percentage of heating energy consumed by fans, assume 3.14%¹⁰⁹⁸
- 29.3 = Conversion from therms to kWh

For example, for a single family home in Mason City installing a new 21 ft² insulated door with an R-value of 11, savings with a gas furnace with system efficiency of 74%:

$$\begin{aligned}\Delta\text{kWh}_{\text{gas_heating}} &= 10.0 * 0.0314 * 29.3 \\ &= 9.2 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta\text{kW} = (\Delta\text{kWh}_{\text{cooling}} / \text{FLH}_{\text{cooling}}) * \text{CF}$$

Where:

- $\text{FLH}_{\text{cooling}}$ = Full load hours of air conditioning
- = Dependent on location:¹⁰⁹⁹

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

¹⁰⁹⁸ 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 (E_f in MMBtu/yr) and E_{ae} (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.

¹⁰⁹⁹ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

CF = Summer System Peak Coincidence Factor for Cooling
 = 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹¹⁰⁰ 43.1% for ductless HP used as supplemental or limited zone¹¹⁰¹

For example, for a single family home in Mason City installing a new 21 ft² insulated door with an R-value of 11, savings for a 9.8 SEER2 central AC system:

$$\begin{aligned}\Delta kW &= 5.4 / 489 * 0.68 \\ &= 0.0075 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * \text{HDD} * 24}{(100,000 * \eta_{\text{heatGas}})}$$

Where:

R_{existing} = Existing door heat loss [(hr·°F·ft²)/Btu]
 R_{new} = New door heat loss coefficient [(hr·°F·ft²)/Btu]
 Area = Area of the door surface in square feet.
 HDD = Heating Degree Days
 = Dependent on location:¹¹⁰²

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

100,000 = Conversion from BTUs to Therms
 η_{heatGas} = Efficiency of gas heating system
 = Equipment efficiency * distribution efficiency
 = Actual¹¹⁰³. If using rated efficiencies, derate efficiency value by 1% per year (maximum

¹¹⁰⁰ 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)’.

¹¹⁰¹ Based on analysis of metering results from Ameren Illinois; Cadmus, “All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems”, October 6, 2015.

¹¹⁰² 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.

¹¹⁰³ 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: ([See: “BPI, Distribution Efficiency Table”](#)) or by performing duct blaster testing.

of 30 years) to account for degradation over time.¹¹⁰⁴ If unknown, assume 74% for unsealed ducts¹¹⁰⁵ or 87% for sealed ducts.

For example, for a single family home in Mason City installing a new 21 ft² insulated door with an R-value of 11, savings with a gas furnace with system efficiency of 74%:

$$\begin{aligned}\Delta\text{Therms} &= (((1/3.125 - 1/11) * 21 * 6,391 * 24) / (100,000 * 0.74)) \\ &= 10.0 \text{ therms}\end{aligned}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

$$\begin{aligned}\Delta\text{Therms} &= \text{Therm impact calculated above} \\ \text{GCF} &= \text{Gas Coincidence Factor for Heating}^{1106} \\ &= 0.014378 \text{ for Residential Boiler} \\ &= 0.016525 \text{ for Residential Space Heating (other)}\end{aligned}$$

For example, for a single family home in Mason City installing a new 21 ft² insulated door with an R-value of 11, savings with a gas furnace with system efficiency of 74%:

$$\begin{aligned}\Delta\text{PeakTherms} &= 10.0 * 0.016525 \\ &= 0.1653 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-DOOR-V06-260101

SUNSET DATE: 1/1/2029

¹¹⁰⁴ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

¹¹⁰⁵ 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: $((0.60 * 0.92) + (0.40 * 0.8)) * (1 - 0.15) = 0.74$.

¹¹⁰⁶ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

2.6.6 Floor Insulation Above Crawl Space

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 does not 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 20 years.¹¹⁰⁷

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

¹¹⁰⁷ As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018.

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.

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

Where:

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})} \right) * Area * (1 - Framing Factor) * CDD * 24 * DUA}{(1,000 * \eta_{Cool})}$$

R_{Old} = R-value value of floor before insulation, assuming 3/4" plywood subfloor and carpet with pad

= Actual. If unknown assume 3.96¹¹⁰⁸

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

= Actual¹¹⁰⁹

Area = Total floor area to be insulated

Framing Factor = Adjustment to account for area of framing

= 12%¹¹¹⁰

24 = Converts hours to days

CDD = Cooling Degree Days

Climate Zone (City based upon)	Unconditioned Space
	CDD 75 ¹¹¹¹
Zone 5 (Burlington)	411
Zone 6 (Mason City)	264
Average/ unknown	474

¹¹⁰⁸ Based on 2005 ASHRAE Handbook – Fundamentals: assuming 2x8 joists, 16" OC, 3/4" subfloor, 1/2" carpet with rubber pad, and accounting for a still air film above and below: $1 / [(0.85 \text{ cavity share of area} / (0.68 + 0.94 + 1.23 + 0.68)) + (0.15 \text{ framing share} / (0.68 + 7.5" * 1.25 \text{ R/in} + 0.94 + 1.23 + 0.68))] = 3.96$

¹¹⁰⁹ 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.

¹¹¹⁰ ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

¹¹¹¹ 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. 75°F for cooling and 50°F for heating are used based on professional judgment. Five year average cooling degree days with 75°F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72°F.

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).
= 0.75¹¹¹²

1000 = Converts Btu to kWh

η_{Cool} = Seasonal Energy Efficiency Ratio 2 of cooling system (kBtu/kWh)¹¹¹³
= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹¹⁴ If unknown assume the following:¹¹¹⁵

Age of Equipment	η_{Cool} Estimate Sealed Duct Estimate	η_{Cool} Unsealed Duct Estimate (η_{Cool} Sealed * 0.85)
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015 - 2022	12.4	10.5
Heat Pump 2015 - 2022	13.3	11.3
Central AC After 1/1/2023	13.4	11.4
Heat Pump After 1/1/2023	14.3	12.2

Heat_elec = Flag variable dependent on heating system fuel type
= 1 if electric heating system
= 0 if gas furnace

$\Delta kWh_{elec_heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})} \right) * Area * (1 - Framing Factor) * HDD * 24 * ADJ_{Floor}}{(\eta_{HeatElec} * 3,412)}$$

HDD = Heating Degree Days:

¹¹¹² Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

¹¹¹³ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

¹¹¹⁴ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹¹⁵ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

Climate Zone (City based upon)	Unconditioned Space
	HDD 50 ¹¹¹⁶
Zone 5 (Burlington)	2,678
Zone 6 (Mason City)	4,222
Average/ unknown	3,126

η_{HeatElec} = Efficiency of electric heating system¹¹¹⁷

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹¹⁸ If not available refer to default table below:¹¹¹⁹

System Type	Age of Equipment	HSPF2 Estimate	η_{Heat} (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	n_{Heat} (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015 - 2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2
Resistance	N/A	N/A	1.00	1.00

ADJ_{Floor} = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings.

= 88%¹¹²⁰

Other factors as defined above

¹¹¹⁶ 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. 75°F for cooling and 50°F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

¹¹¹⁷ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹¹¹⁸ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹¹⁹ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

¹¹²⁰ 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.

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 9.8 SEER2 Central AC and a newer heat pump:

$$\begin{aligned}\Delta kWh &= \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_elec) + (\Delta kWh_{gas_heating} * (1 - \\ &Heat_elec))) \\ &= (((1/3.96 - 1/(30+3.96)) * (20*25) * (1-0.12) * 24 * 264 * 0.75) / (1,000 * 9.8)) + (((1/3.96 - \\ &1/(30+3.96)) * (20*25) * (1-0.12) * 24 * 4,222) / (3412 * 1.62)) * 0.88 * 1) + (0 * (1 - 1)) \\ &= (47.6 + 1,583.4) \\ &= 1,631 kWh\end{aligned}$$

$$\begin{aligned}\Delta kWh_{gas_heating} &= \text{If gas furnace heat, kWh savings for reduction in fan run time} \\ &= \Delta Therms * F_e * 29.3\end{aligned}$$

Where:

$$\begin{aligned}F_e &= \text{Furnace Fan energy consumption as a percentage of annual fuel consumption} \\ &= 3.14\%^{1121} \\ 29.3 &= \text{kWh per therm}\end{aligned}$$

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):

$$\begin{aligned}\Delta kWh &= 118.3 * 0.0314 * 29.3 \\ &= 108.8 kWh\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

$$\begin{aligned}FLH_{cooling} &= \text{Full load hours of air conditioning} \\ &= \text{Dependent on location:}^{1122}\end{aligned}$$

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

¹¹²¹ 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 (E_f in MMBtu/yr) and E_{ae} (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.

¹¹²² 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

CF = Summer System Peak Coincidence Factor for Cooling
 = 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹¹²³ 43.1% for ductless HP used as supplemental or limited zone¹¹²⁴

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 9.8 SEER2 Central AC and a newer heat pump:

$$\begin{aligned}\Delta kW &= 47.6 / 489 * 0.68 \\ &= 0.0662 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

$$\begin{aligned}&\Delta \text{Therms (if Natural Gas heating)} \\ &= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})} \right) * Area * (1 - Framing Factor) * HDD * 24 * ADJ_{Floor}}{(\eta_{HeatGas} * 100,000)}\end{aligned}$$

Where:

$\eta_{HeatGas}$ = Efficiency of gas heating system
 = Equipment efficiency * distribution efficiency
 = Actual¹¹²⁵. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹²⁶ If unknown, assume 74% for unsealed ducts¹¹²⁷ or 87% for sealed ducts
 100,000 = Converts Btu to Therms
 Other factors as defined above

¹¹²³ 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)'.

¹¹²⁴ Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

¹¹²⁵ 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: (See: "BPI, Distribution Efficiency Table") or by performing duct blaster testing.

¹¹²⁶ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹²⁷ 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:

$$\Delta\text{Therms} = (((1/3.96 - 1/(30+3.96)) * (20*25) * (1-0.12) * 24 * 4,222) / (100,000 * 0.74)) * 0.88$$

$$= 118.3 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹¹²⁸

= 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:

$$\Delta\text{PeakTherms} = 118.3 \text{ therms} * 0.016525$$

$$= 1.95 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-FINS-V07-260101

SUNSET DATE: 1/1/2029

¹¹²⁸ 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 does not 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 20 years.¹¹²⁹

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

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 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.

¹¹²⁹ As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

Where:

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})} \right) * L_{BWT} * H_{BWAG} * (1 - FF) * CDD * 24 * DUA}{(1,000 * \eta_{Cool})}$$

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

= Actual¹¹³⁰

R_{OldAG} = R-value value of foundation wall above grade.

= Actual, if unknown assume 1.0¹¹³¹

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 Rigid Foam

= 25% if studs and cavity insulation¹¹³²

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space
	CDD 65 ¹¹³³	CDD 75 ¹¹³⁴
Zone 5 (Burlington)	1,209	411
Zone 6 (Mason City)	616	264
Average/ unknown	1,068	474

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

¹¹³⁰ 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.

¹¹³¹ 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.”

¹¹³² ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1

¹¹³³ National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

¹¹³⁴ 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. 75°F for cooling and 50°F for heating are used based on professional judgment. Five year average cooling degree days with 75°F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72°F.

$$= 0.75^{1135}$$

1000 = Converts Btu to kBtu

η_{Cool} = Seasonal Energy Efficiency Ratio 2 of cooling system (kBtu/kWh)¹¹³⁶

= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹³⁷ If unknown assume the following:¹¹³⁸

Age of Equipment	η_{Cool} Sealed Duct Estimate	η_{Cool} Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015 - 2022	12.4	10.5
Heat Pump 2015 - 2022	13.3	11.3
Central AC After 1/1/2023	13.4	11.4
Heat Pump After 1/1/2023	14.3	12.2

Heat_elec = Flag variable dependent on heating system fuel type

= 1 if electric heating system

= 0 if gas furnace

$\Delta kWh_{elec_heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\left(\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})} \right) * L_{BWT} * H_{BWAG} * (1 - FF) \right) + \left(\left(\frac{1}{R_{OldBG}} - \frac{1}{(R_{Added} + R_{OldBG})} \right) * L_{BWT} * (H_{BWT} - H_{BWAG}) * (1 - FF) \right) \right) * HDD * 24 * DUA * ADJ_{Basement}}{(3,412 * \eta_{HeatElec})}$$

Where:

R_{OldBG} = R-value value of foundation wall below grade (including thermal resistance of the earth)¹¹³⁹

= dependent on depth of foundation (H_basement_wall_total -

¹¹³⁵ 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.

¹¹³⁶ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

¹¹³⁷ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹³⁸ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

¹¹³⁹ Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

$H_{\text{basement_wall_AG}}$:

= 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·ft ² ·h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69
Total BG R-value (earth + R-1.0 foundation) default	3.44	4.47	5.41	6.41	7.42	8.46	9.46	10.53	11.69

H_{BWT} = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space
	HDD 60 ¹¹⁴⁰	HDD 50 ¹¹⁴¹
Zone 5 (Burlington)	4,496	2,678
Zone 6 (Mason City)	6,391	4,222
Average/ unknown	5,052	3,126

η_{HeatElec} = Efficiency of electric heating system¹¹⁴²

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹⁴³ If not available refer to default table below:¹¹⁴⁴

¹¹⁴⁰ 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.

¹¹⁴¹ 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. 75°F for cooling and 50°F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

¹¹⁴² If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹¹⁴³ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

¹¹⁴⁴ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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	HSPF2 Estimate	η Heat (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015 - 2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2
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%¹¹⁴⁵

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, 9.8 SEER2 Central AC and 1.91 COP heat pump:

$$\begin{aligned}
 \Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + ((\Delta \text{kWh}_{\text{elec_heating}} * \text{Heat}_{\text{elec}}) + (\Delta \text{kWh}_{\text{gas_heating}} * (1 - \text{Heat}_{\text{elec}}))) \\
 &= [(((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1 - 0)) * 24 * 264 * 0.75)/(1,000 * 9.8)] + \\
 &\quad [((((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0)) + ((1 / (2.25 + 6.42) - 1 / (13 + 2.25 + 6.42)) * (20+25+20+25) * 4 * (1-0))) * 24 * 4,222) / (3,412 * 1.62)) * 0.88 * 1] + (0 - (1 - 1)) \\
 &= (49.6 + 2,052.1) \\
 &= 2,101.7 \text{ kWh}
 \end{aligned}$$

 $\Delta \text{kWh}_{\text{gas_heating}}$ = If gas *furnace* heat, kWh savings for reduction in fan run time= $\Delta \text{Therms} * F_e * 29.3$ F_e

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

= 3.14%¹¹⁴⁶

29.3

= kWh per therm

¹¹⁴⁵ 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.

¹¹⁴⁶ 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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e . See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For example, 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):

$$\begin{aligned}\Delta kWh_{\text{gas_heating}} &= 153.3 * 0.0314 * 29.3 \\ &= 141 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND

$$\Delta kW = \frac{\Delta kWh_{\text{cooling}}}{FLH_{\text{cooling}}} * CF$$

Where:

FLH_{cooling} = Full load hours of air conditioning
= Dependent on location:¹¹⁴⁷

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

CF = Summer System Peak Coincidence Factor for Cooling
= 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹¹⁴⁸ 43.1% for ductless HP used as supplemental or limited zone¹¹⁴⁹

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, 9.8 SEER2 Central AC and 1.91 COP heat pump:

$$\begin{aligned}\Delta kW &= 49.6 / 489 * 0.68 \\ &= 0.069 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If Natural Gas heating:

$$\Delta \text{Therms} =$$

¹¹⁴⁷ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹¹⁴⁸ 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)'.

¹¹⁴⁹ Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

$$= \frac{\left(\left(\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})} \right) * L_{BWT} * H_{BWAG} * (1 - FF) \right) + \left(\left(\frac{1}{R_{OldBG}} - \frac{1}{(R_{Added} + R_{OldBG})} \right) * L_{BWT} * (H_{BWT} - H_{BWAG}) * (1 - FF) \right) \right) * HDD * 24 * ADJ_{Basement}}{(100,000 * \eta_{HeatGas})}$$

Where:

$\eta_{HeatGas}$ = Efficiency of gas heating system
 = Equipment efficiency * distribution efficiency
 = Actual¹¹⁵⁰. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹⁵¹ If unknown, assume 74% for unsealed ducts¹¹⁵² 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:

$$= ((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0) + (1/8.67 - 1/(13 + 8.67)) * (20+25+20+25) * 4 * (1 - 0)) * 24 * 4222 / (0.74 * 100,000) * 0.88$$

$$= 153.3 \text{ therms}$$

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹¹⁵³
 = 0.014378 for Residential Boiler
 = 0.016525 for Residential Space Heating (other)

¹¹⁵⁰ 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: (See: "BPI, Distribution Efficiency Table") or by performing duct blaster testing.

¹¹⁵¹ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

¹¹⁵² 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.

¹¹⁵³ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

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:

$$\begin{aligned}\Delta\text{PeakTherms} &= 153.3 \text{ therms} * 0.016525 \\ &= 2.53 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-BINS-V07-260101

SUNSET DATE: 1/1/2029

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.¹¹⁵⁴

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be \$4.00 per square foot of window area.¹¹⁵⁵

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

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

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

Where:

$\Delta kWh_{cooling}$ = If central cooling, reduction in annual cooling requirement due to insulation

¹¹⁵⁴ Consistent with window measure lives specified in the MidAmerican Energy Company Joint Assessment, February 2013.

¹¹⁵⁵ NEEA “Study of High-Performance Windows Incremental Manufacturing Cost” January 3rd, 2023..

$$= \frac{(U_{code} - U_{eff}) * A_{window} * CDD * 24 * DUA}{(1,000 * \eta_{cool})}$$

U_{code} = U-factor value of code baseline (IECC2012) window assembly (Btu/ft²·°F·h)
= 0.32 (Btu/ft²·°F·h) or 0.55 (Btu/ft²·°F·h) for skylights.

U_{eff} = U-factor value of the efficient window assembly (Btu/ft²·°F·h)
= Actual.

A_{window} = Area of insulated window (including visible framing and glass) (ft²)

CDD = Cooling Degree Days
= Dependent on location:¹¹⁵⁶

Climate Zone (City based upon)	CDD 65
Zone 5 (Burlington)	1,209
Zone 6 (Mason City)	616
Average/ unknown	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 ¹¹⁵⁷

1000 = Converts Btu to kWh

η_{cool} = Seasonal Energy Efficiency Ratio 2 of cooling system (kBtu/kWh)¹¹⁵⁸
= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹⁵⁹ If unknown, assume the following:¹¹⁶⁰

Age of Equipment	η_{Cool} Sealed Duct Estimate	η_{Cool} Unsealed Duct Estimate (nCool Sealed * 0.85)
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015 - 2022	12.4	10.5
Heat Pump 2015 - 2022	13.3	11.3

¹¹⁵⁶ National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

¹¹⁵⁷ 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.

¹¹⁵⁸ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

¹¹⁵⁹ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

¹¹⁶⁰ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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	η_{Cool} Sealed Duct Estimate	η_{Cool} Unsealed Duct Estimate (η_{Cool} Sealed * 0.85)
Central AC after 1/1/2023	13.4	11.4
Heat Pump after 1/1/2023	14.3	12.2

Heat_elec = Flag variable dependent on heating system fuel type
 = 1 if electric heating system
 = 0 if gas furnace

$\Delta kWh_{elec_heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{(U_{code} - U_{eff}) * A_{window} * HDD * 24 * ADJ_{window}}{(\eta_{heatElec} * 3412)}$$

HDD = Heating Degree Days
 = Dependent on location:¹¹⁶¹

Climate Zone (City based upon)	HDD 60
Zone 5 (Burlington)	4,496
Zone 6 (Mason City)	6,391
Average/ unknown	5,052

$\eta_{heatElec}$ = Efficiency of electric heating system¹¹⁶²
 = Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time. ¹¹⁶³ If not available, refer to default table below:¹¹⁶⁴

System Type	Age of Equipment	HSPF2 Estimate	η_{Heat} (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	η_{Heat} (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015 - 2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2

¹¹⁶¹ 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.

¹¹⁶² If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹¹⁶³ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹⁶⁴ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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	HSPF2 Estimate	η Heat (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
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%¹¹⁶⁵

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 for a 9.8 SEER2 Central AC system and a 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}
 \Delta kWh &= \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})) \\
 &= (((((0.32 - 0.25) * 8 * 616 * 24 * 0.75) / (1,000 * 9.8)) + (((((0.32 - 0.25) * 8 * 6,391 * 24 * 0.63) / (1.62 * 3,412))) * 1) + (0 - (1 - 1))) * 15 \\
 &= 10 kWh + 147 kWh \\
 &= 157 kWh
 \end{aligned}$$

$\Delta kWh_{gas_heating}$ = 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%¹¹⁶⁶

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%:

$$\begin{aligned}
 \Delta kWh &= 11 * 0.0314 * 29.3 \\
 &= 10 kWh
 \end{aligned}$$

¹¹⁶⁵ 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.

¹¹⁶⁶ 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 (E_f in MMBtu/yr) and E_{ae} (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:¹¹⁶⁷

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown	861	690	811

CF = Summer System Peak Coincidence Factor for Cooling
 = 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹¹⁶⁸ 43.1% for ductless HP used as supplemental or limited zone¹¹⁶⁹

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 9.8 SEER2 Central AC system and a 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}\Delta kW &= 10 / 489 * 0.68 \\ &= 0.0139 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{(U_{code} - U_{eff}) * A_{window} * HDD * 24 * ADJ_{window}}{(\eta_{heatGas} * 100,000)}$$

Where:

η_{heatGas} = Efficiency of gas heating system
 = Equipment efficiency * distribution efficiency
 = Actual¹¹⁷⁰. If using rated efficiencies, derate efficiency value by 1% per year (maximum

¹¹⁶⁷ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹¹⁶⁸ 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)'.

¹¹⁶⁹ Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

¹¹⁷⁰ 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: ([See: "BPI, Distribution Efficiency Table"](#)) or by performing duct blaster testing.

of 30 years) to account for degradation over time.¹¹⁷¹ If unknown, assume 74% for unsealed ducts¹¹⁷² 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%:

$$\begin{aligned}\Delta\text{Therms} &= [(0.32 - 0.25) * 8 * 6,391 * 24 * 0.63] / (0.74 * 100,000)) * 15 \\ &= 11 \text{ therms}\end{aligned}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹¹⁷³

= 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%:

$$\begin{aligned}\Delta\text{PeakTherms} &= 11 * 0.016525 \\ &= 0.18 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-WINS-V07-270101

SUNSET DATE: 1/1/2030

¹¹⁷¹ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹⁷² 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: $((0.60 * 0.92) + (0.40 * 0.8)) * (1 - 0.15) = 0.74$.

¹¹⁷³ Calculated using Cadmus provided Gas Loadshapes as the maximum daily load for the end use.

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

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Old} + R_{New}} \right) * A_{window} * HDD * 24 * ADJ_{window}}{(\eta_{heatElec} * 3412)}$$

R_{Old} = R-value value of existing window assembly (ft²·°F·h/Btu)

= Actual. If unknown, assume R-2¹¹⁷⁴

R_{New} = R-value of added air layer (ft²·°F·h/Btu)

= R-2.85¹¹⁷⁵

A_{window} = Net area of insulated window (ft²)

= Actual. If unknown, assume 8 ft² (24 inch x 48 inch)

HDD = Heating Degree Days

= Dependent on location:¹¹⁷⁶

Climate Zone (City based upon)	GHCNd ID	Official Name	HDD 60	HDD 60 / 365
Zone 5 (Burlington)	USC00131060	BURLINGTON 2S, IA US	4,832	13.24
Zone 6 (Mason City)	USW00014940	MASON CITY MUNI AP, IA US	6,356	17.41
Average (Des Moines) ¹¹⁷⁷	USW00014933	DES MOINES INTL AP, IA US	5,013	13.73

$\eta_{heatElec}$ = Efficiency of electric heating system¹¹⁷⁸

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹⁷⁹ If not available, refer to default table below:¹¹⁸⁰

¹¹⁷⁴ 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.

¹¹⁷⁵ 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 an R-value of 2.85 is expected for any air gap greater than 0.5 inches.

¹¹⁷⁶ National Climatic Data Center, Annual Normals calculated by NCDC, 15-year span from 2006-2020, with a base temp of 60°F.

¹¹⁷⁷ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹¹⁷⁸ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹¹⁷⁹ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

¹¹⁸⁰ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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	HSPF2 Estimate	η Heat (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015 - 2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2
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 consistently overclaiming savings
= 63%¹¹⁸¹

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 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}\Delta kWh &= \Delta kWh_{heating} \\ &= [(1/2 - 1/(2+4)) * 8 * 6,356 * 24 * 0.63] / (1.62 * 3,412)) * 15 \\ &= 695 \text{ kWh}\end{aligned}$$

$\Delta kWh_{heating}$ = If gas *furnace* heat, kWh savings for reduction in fan run time
= Δ Therms * F_e * 29.3

Where:

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
= 3.14%¹¹⁸²

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%:

$$\begin{aligned}\Delta kWh &= 52 * 0.0314 * 29.3 \\ &= 48 \text{ kWh}\end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

¹¹⁸¹ 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.

¹¹⁸² 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 (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1,495 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.

NATURAL GAS SAVINGS

Δ Therms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Old} + R_{New}} \right) * A_{window} * HDD * 24 * ADJ_{window}}{(\eta_{heatGas} * 100,000)}$$

Where:

$\eta_{HeatGas}$ = Efficiency of gas heating system
 = Equipment efficiency * distribution efficiency
 = Actual¹¹⁸³. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹⁸⁴ If unknown, assume 74% for unsealed ducts¹¹⁸⁵ 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%:

$$\Delta \text{Therms} = [(1/2 - 1/(2+4)) * 8 * 5,943 * 24 * 0.63] / (0.74 * 100,000) * 15$$

= 52 therms

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * GCF$$

Where:

Δ Therms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹¹⁸⁶
 = 0.014378 for Residential Boiler
 = 0.016525 for Residential Space Heating (other)

¹¹⁸³ 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: ([See: "BPI, Distribution Efficiency Table"](#)) or by performing duct blaster testing.

¹¹⁸⁴ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹⁸⁵ 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.

¹¹⁸⁶ 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 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%:

$$\begin{aligned}\Delta\text{PeakTherms} &= 52 * 0.016525 \\ &= 0.86 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-WINK-V05-260101

SUNSET DATE: 1/1/2030

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

The expected measure life is assumed to be 20 years.¹¹⁸⁷

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/ft² of window area (material cost) plus \$30 per window for installation expenses.¹¹⁸⁸ For clear glazing, cost can be assumed as \$6.72/ft² of window area (material cost) plus \$30 per window for installation expenses.¹¹⁸⁹

LOADSHAPE

Loadshape RE06 – Residential Single Family Central Heat

Loadshape RE07 – Residential Single Family Cooling

Loadshape RE08 – Residential Single Family Heat Pump

Loadshape RG01 – Residential Boiler

Loadshape RG04 – Residential Other Heating

¹¹⁸⁷ 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.

¹¹⁸⁸ 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.

¹¹⁸⁹ 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/ft². Installation costs are identical.

Algorithm

CALCULATION OF SAVINGS

The following reference tables show savings factors (kBtu/ft²) for both heating and cooling loads for each of the weather zones defined by the TRM.¹¹⁹⁰ 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

¹¹⁹⁰ Savings factors are based on simulation results, documented in “Storm Windows Savings.xlsx”

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	14.9	7.6	14.4	6.9
	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

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	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/ft ²		Base Window Assembly			
		Single Pane, Double Hung	Double Pane, Double Hung	Single Pane, Fixed	Double Pane, Fixed
Storm Window Type	Clear Exterior	20.0	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

$$\Delta kWh = \Delta kWh_{cooling} + ((\Delta kWh_{elec_heating} * Heat_{elec}) + (\Delta kWh_{gas_heating} * (1 - Heat_{elec})))$$

Where:

$\Delta kWh_{cooling}$ = If storm windows are left installed during the cooling season and the home has central cooling, the reduction in annual cooling requirement

$$= \frac{\varphi_{cool} * A}{\eta_{Cool}}$$

φ_{cool} = Savings factor for cooling, as tabulated above.

A = Area (square footage) of storm windows installed.

η_{Cool} = Efficiency (SEER2) of Air Conditioning equipment (kBtu/kWh)¹¹⁹¹

= Actual (where it is possible to measure or reasonably estimate). If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to

¹¹⁹¹ If existing equipment is rated in SEER metrics, convert by multiplying the SEER rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted/Packaged 0.95 or Ductless 1.00.

account for degradation over time. ¹¹⁹² If unknown, assume the following:¹¹⁹³

Age of Equipment	SEER2 Sealed Estimate	SEER2 Unsealed Estimate
Before 2006	9.5	8.1
2006 – 2014	12.4	10.5
Central AC 2015 - 2022	12.4	10.5
Heat Pump 2015 - 2022	13.3	11.3
Central AC After 1/1/2023	13.4	11.4
Heat Pump After 1/1/2023	14.3	12.2

Heat_elec = Flag variable dependent on heating system fuel type
 = 1 if electric heating system
 = 0 if gas furnace

ΔkWh_elec_heating = If electric heat (resistance or heat pump), reduction in annual electric heating.

$$= \frac{\varphi_{heat} * A}{\eta_{HeatElec} * 3.412}$$

Where:

φ_{heat} = Savings factor for heating, as tabulated above.

$\eta_{HeatElec}$ = Efficiency of electric heating system¹¹⁹⁴

= Actual. If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹¹⁹⁵ If not available refer to default table below:¹¹⁹⁶

¹¹⁹² Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹⁹³ These default system efficiencies are based on the applicable minimum Federal Standards. 10 CFR § 430.32 - Energy and water conservation standards and their compliance dates. | Electronic Code of Federal Regulations (e-CFR) | US Law | LII / Legal Information Institute. 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.

¹¹⁹⁴ If existing equipment is rated in HSPF metrics, convert by multiplying the HSPF rating by the following factors depending on equipment type provided in the CEE Crosswalk: Ducted 0.85, Ductless 0.90, Packaged 0.84.

¹¹⁹⁵ Justification for degradation factors is based on review of a number of studies including: NREL, “Building America Performance Analysis Procedures for Existing Homes”, May 2006 and Cadmus, “Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013”, May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^Equipment Age).

¹¹⁹⁶ 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	HSPF2 Estimate	η Heat (Effective COP Estimate) with unsealed ducts (HSPF2/3.412)*0.85	nHeat (Effective COP Estimate) with Sealed Ducts (HSPF2/3.412)
Heat Pump	Before 2006	5.8	1.45	1.7
	2006 – 2014	6.5	1.62	1.91
	2015 - 2022	7	1.74	2.05
	2023 and after	7.5	1.87	2.2
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 9.8 SEER2 Central AC system and a 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}
 \Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + ((\Delta \text{kWh}_{\text{elec_heating}} * \text{Heat_elec}) + (\Delta \text{kWh}_{\text{gas_heating}} * (1 - \text{Heat_elec}))) \\
 &= (((11.8 * 8) / 9.8) + (((32.4 * 8) / (1.62 * 3.412)) * 1 + (0 * (1 - 1))) * 15 \\
 &= 144 \text{ kWh} + 703 \text{ kWh} \\
 &= 847 \text{ kWh}
 \end{aligned}$$

$\Delta \text{kWh}_{\text{gas_heating}}$ = If gas furnace heat, kWh savings for reduction in fan run time
 = $\Delta \text{Therms} * F_e * 29.3$

Where:

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
 = 3.14%¹¹⁹⁷

29.3 = kWh per therm

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%:

$$\begin{aligned}
 \Delta \text{kWh}_{\text{gas_heating}} &= 52 * 0.0314 * 29.3 \\
 &= 48 \text{ kWh}
 \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh_{\text{cooling}}}{FLH_{\text{cooling}}} * CF$$

¹¹⁹⁷ 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 (E_f in MMBtu/yr) and E_{ae} (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.

Where:

FLH_{cooling} = Full load hours of air conditioning
= Dependent on location:¹¹⁹⁸

Climate Zone (City based upon)	Single Family	Multifamily	Manufactured
Zone 5 (Burlington)	977	784	921
Zone 6 (Mason City)	489	392	461
Average/ unknown ¹¹⁹⁹	861	690	811

CF = Summer System Peak Coincidence Factor for Cooling
= 68% if central AC; 72% if ducted ASHP or ductless HP used for whole home conditioning;¹²⁰⁰ 43.1% for ductless HP used as supplemental or limited zone¹²⁰¹

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 9.8 SEER2 Central AC system and a 1.91 (1.62 including distribution losses) COP heat pump:

$$\begin{aligned}\Delta kW &= 144 / 489 * 0.68 \\ &= 0.2002 \text{ kW}\end{aligned}$$

NATURAL GAS SAVINGS

If Natural Gas heating:

$$\Delta Therms = \frac{\phi_{heat} * A}{\eta_{HeatGas} * 100}$$

Where:

$\eta_{HeatGas}$ = Efficiency of gas heating system
= Equipment efficiency * distribution efficiency
= Actual¹²⁰². If using rated efficiencies, derate efficiency value by 1% per year (maximum of 30 years) to account for degradation over time.¹²⁰³ If not available, use 74% for

¹¹⁹⁸ 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). In 2024, the change to CDD from 30-yr to 15-yr NCDC data was applied to these values. Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹¹⁹⁹ Des Moines represents the average of the state, used when location is unknown. Please see IA TRM Section 6.8 Weather Data for weather-sensitive measures for further details.

¹²⁰⁰ 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)'.

¹²⁰¹ Based on analysis of metering results from Ameren Illinois; Cadmus, "All-Electric Homes: PY6 Metering Results: Multifamily HVAC Systems", October 6, 2015.

¹²⁰² 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: (See: "BPI, Distribution Efficiency Table") or by performing duct blaster testing.

¹²⁰³ Justification for degradation factors is based on review of a number of studies including: NREL, "Building America Performance Analysis Procedures for Existing Homes", May 2006 and Cadmus, "Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013", May 2014. Estimate efficiency as (Rated Efficiency * (1-0.01)^{Equipment Age}).

unsealed ducts¹²⁰⁴ 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%:

$$\Delta \text{Therms} = ((32.4 * 8) / (0.74 * 100)) * 15$$

$$= 52.5 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating¹²⁰⁵

= 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%:

$$\Delta \text{PeakTherms} = 52.5 * 0.016525$$

$$= 0.8676 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-STRM-V05-260101

SUNSET DATE: 1/1/2026*

* Currently, no utilities are offering this measure, and it is therefore overdue for a reliability review. If a utility plans to start using this measure again it should be reviewed accordingly.

¹²⁰⁴ 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: $((0.60 * 0.92) + (0.40 * 0.8)) * (1 - 0.15) = 0.74$.

¹²⁰⁵ 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

Residential pool pumps can be single speed, two/multi speed or variable speed. A federal standard (82 FR 5650) effective July 19, 2021, effectively requires new pumps to be at least two-speed.

Single speed pumps are often oversized and run frequently at constant flow regardless of load. Single speed pool pumps require that the motor be sized for the task that requires the highest speed. As such, energy is wasted performing low speed tasks at high speed. Two-speed and variable speed pool pumps reduce speed when less flow is required, such as when filtering is needed but not cleaning, and have timers that encourage programming for fewer on-hours. Variable speed pool pumps use advanced motor technologies to achieve efficiency ratings of 90% while the average single speed pump will have efficiency ratings between 30% and 70%.¹²⁰⁶

This measure applies to the purchase and installation of a new ENERGY STAR¹²⁰⁷ variable speed residential pool pump motor in place of a new baseline pump meeting the federal standard for Time of Sale and New Construction, or the early replacement of a standard single speed motor of equivalent horsepower.

The new federal and ENERGY STAR standards now provide specifications for above ground in addition to in ground pool pumps.

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 residential pool pump. ENERGY STAR Pool Pump Specification Version 3.0 became effective on July 19, 2021. This characterization assumes incentivized products meet Version 3.0 requirements provided below:

Pump Sub-Type	Size Class	Version 3.0 Energy Efficiency Level (Effective 7/19/2021)
Self-Priming (Inground) Pool Pumps	Extra Small (hhp $\leq$ 0.13)	WEF $\geq$ 13.40
	Small (hhp $>$ 0.13 and $<$ 0.711)	WEF $\geq -2.45 \times \ln(\text{hhp}) + 8.40$
	Standard Size (hhp $\geq$ 0.711)	WEF $\geq -2.45 \times \ln(\text{hhp}) + 8.40$
Non-Self Priming (Aboveground) Pool Pumps	Extra Small (hhp $\leq$ 0.13)	WEF $\geq$ 4.92
	Standard Size (hhp $>$ 0.13)	WEF $\geq -1.00 \times \ln(\text{hhp}) + 3.85$

DEFINITION OF BASELINE EQUIPMENT

For TOS and NC, the baseline equipment is a two-speed residential pool pump meeting the Federal Standard, effective July 19, 2021, provided below:

Pump Sub-Type	Size Class	Baseline (Effective 7/19/2021)
	Extra Small (hhp $\leq$ 0.13)	WEF $\geq$ 5.55

¹²⁰⁶ U.S. DOE, 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. Report No. DOE/GO-102012-3534.

¹²⁰⁷ In the event that the ENERGY STAR program is ended, the last effective ENERGY STAR specification and corresponding Qualified Products List should continue to be used through the effective period of this TRM.

Pump Sub-Type	Size Class	Baseline (Effective 7/19/2021)
Self-Priming (Inground) Pool Pumps	Small (hhp > 0.13 and < 0.711)	$WEF \geq -1.30 \times \ln(hhp) + 2.90$
	Standard Size (hhp $\geq$ 0.711)	$WEF \geq -2.30 \times \ln(hhp) + 6.59$
Non-Self Priming (Aboveground) Pool Pumps	Extra Small (hhp $\leq$ 0.13)	$WEF \geq 4.60$
	Standard Size (hhp > 0.13)	$WEF \geq -0.85 \times \ln(hhp) + 2.87$

For retrofit, the baseline is the existing single speed pool pump.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for an ENERGY STAR pool pump is 10 years.¹²⁰⁸

For retrofit, the estimated remaining useful life of the existing single speed pump is 4 years.

DEEMED MEASURE COST

For TOS and NC, the incremental cost is estimated as \$314¹²⁰⁹ for in-ground pumps and are estimated as \$840¹²¹⁰ for above ground pool pumps.

For retrofit, the full replacement costs shall be used. A deferred new baseline cost (after 4 years) of replacing the existing equipment should also be included.

LOADSHAPE

Loadshape RE17 – Residential Pool Pumps

¹²⁰⁸ 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.

¹²⁰⁹ Incremental costs are from 2013 ENERGY STAR Pool Pump Calculator and represent the difference between the two/multi speed incremental cost and the variable speed incremental cost (\$549 - \$235 = \$314).

¹²¹⁰ CEE Efficient Residential Swimming Pool Initiative, December 2012, page 18 and represent the difference between the two/multi speed incremental cost and the variable speed incremental cost (\$1120 - \$280 = \$840).

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS¹²¹¹

For TOS and NC:

$$\Delta kWh = \frac{\text{Gallons} * \text{Turnovers} * \left(\frac{1}{WEF_{Base}} - \frac{1}{WEF_{ESTAR}} \right)}{1000} * \text{Days}$$

For retrofit:

$$\Delta kWh = \frac{\text{Gallons} * \text{Turnovers} * \left(\frac{1}{EF_{Exist}} - \frac{1}{WEF_{ESTAR}} \right)}{1000} * \text{Days}$$

Where:

Gallons = Capacity of the pool

= Actual. If unknown assume:

Pool Type	Gallons
In ground	22,000 ¹²¹²
Above ground	7,540 ¹²¹³

Turnovers = Desired number of pool water turnovers per day

= 2¹²¹⁴

WEF_{Base} = Weighted Energy factor of baseline pump (gal/Wh)¹²¹⁵

Pool Type	WEF _{Base}
In ground	4.6
Above ground	2.6

WEF_{ESTAR} = Weighted Energy Factor of ENERGY STAR pump (gal/Wh)¹²¹⁶

Pool Type	WEF _{ESTAR}
In ground	6.3
Above ground	3.5

EF_{Exist} = Energy Factor of existing single speed pump (gal/Wh)

¹²¹¹ The methodology followed is consistent with the most recent version of the 2020 ENERGY STAR calculator (Pool_Pump_Calculator_2020.05.05_FINAL.xls), however this has not been updated to account for the new federal standard.

¹²¹² Consistent with assumption in the 2020 ENERGY STAR calculator.

¹²¹³ Based on typical pool sizes from “Evaluation of Potential Best Management Practices - Pools, Spas, and Fountains, The California Urban Water Conservation Council”, 2010.

¹²¹⁴ Consistent with assumption in the 2020 ENERGY STAR calculator.

¹²¹⁵ Based on applying the federal standard specifications to the average Curve-C rated hydraulic horsepower (hhp) from the ENERGY STAR Qualified Products List, accessed 3/31/2021, see “2021 IA TRM_Pool Pump Calculator.xls”.

¹²¹⁶ Based on applying the ENERGY STAR specifications to the average Curve-C rated hydraulic horsepower (hhp) from the ENERGY STAR Qualified Products List, accessed 3/31/2021, see “2021 IA TRM_Pool Pump Calculator.xls”.

$= 2.3^{1217}$
 1,000 = Conversion factor from Wh to kWh
 Days = Pool operating days per year
 $= 122^{1218}$

Based on defaults provided above:

Pool Type	ΔkWh	
	TOS/NC	Retrofit
In ground	307.7	1512.1
Above ground	189.5	283.7

SUMMER COINCIDENT PEAK DEMAND SAVINGS

For TOS and NC:

$$\Delta kW = ((kWh/Day_{Base})/(Hrs/Day_{Base}) - (kWh/Day_{ESTAR})/(Hrs/Day_{ESTAR})) * CF$$

For retrofit:

$$\Delta kW = ((kWh/Day_{Exist})/(Hrs/Day_{Exist}) - (kWh/Day_{ESTAR})/(Hrs/Day_{ESTAR})) * CF$$

Where:

kWh/Day = Daily energy consumption of pool pump

Pool Type	$\Delta kWh/day$		
	Base	ESTAR	Exist
In ground	9.5	7.0	19.4
Above ground	5.9	4.3	6.6

Hrs/Day = Daily run hours of pump
 $= (\text{Gallons} * \text{Turnover}) / \text{GPM}$

		Weighted Average GPM ¹²¹⁹	Hours/Day
In ground	Base	43.6	16.8
	ESTAR	32.2	22.8
	Exist	78	9.4
Above ground	Base	44.7	5.6
	ESTAR	27.3	9.2
	Exist	78.1	3.2

¹²¹⁷ Consistent with assumption in the 2020 ENERGY STAR calculator assuming 1.5 HP pump.

¹²¹⁸ Consistent with assumption in the 2020 ENERGY STAR calculator.

¹²¹⁹ The 2013 ENERGY STAR calculator (included in file “2021 IA TRM_Pool Pump Calculator” provided high and low flow and hour assumptions for multi and variable speed pumps. This is used to estimate a weighted average GPM assumption.

CF = Summer peak coincidence Factor for measure
= 83.1%¹²²⁰

Based on defaults provided above:

Pool Type	ΔkW Saved	
	TOS/NC	Retrofit
In ground	0.2152	1.4641
Above ground	0.4793	1.3285

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-MSC-RPLP-V03-220101

SUNSET DATE: 1/1/2025*

* This measure is overdue for a reliability review due to no utility currently offering the measure. If a utility plans to start using this measure again, it should be reviewed accordingly.

¹²²⁰ Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Iowa.

2.7.2 Level 2 Electric Vehicle Charger

DESCRIPTION

The measure is for the purchase of a Level 2 electric vehicle charger consistent with the ENERGY STAR specification for Electric Vehicle Supply Equipment (EVSE) installed for residential household use. Networked chargers enable access to online energy management tools through an EVSE network. Non-networked chargers are standalone units that are not connected to other units through an EVSE network.

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

An ENERGY STAR qualified networked or non-networked level 2 electric vehicle charger.

DEFINITION OF BASELINE EQUIPMENT

A non-ENERGY STAR networked or non-networked level 2 electric vehicle charger.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for the EV charger is assumed to be 10 years.¹²²¹

DEEMED MEASURE COST

The incremental cost for the EV charger is assumed to be \$84 for a non-networked charger and \$47 for a networked charger.¹²²²

LOADSHAPE

Loadshape RE19 – Residential Electric Vehicle Charger

COINCIDENCE FACTOR

Coincidence factor is embedded in deemed demand reduction savings estimate, so the coincidence factor is assumed to be 1.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = (((\text{Hours_PS} + \text{Hours_US}) * \text{SP_base}) - (\text{Hours_PS} * \text{SP_EEp} + \text{Hours_US} * \text{SP_EEu})) / 1,000$$

Where:

$$\begin{aligned} \text{Hours_C} &= \text{Annual Active Charging Hours} \\ &= 278 \text{ hours}^{1223} \end{aligned}$$

¹²²¹ Based on Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See 'Level2EVChargers_v3_1.xlsm'.

¹²²² Based on Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See 'Level2EVChargers_v3_1.xlsm'.

¹²²³ Based on Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See 'Level2EVChargers_v3_1.xlsm'.

Hours_P = Total Annual Hours Plugged In

$$= 3,511 \text{ hours}^{1224}$$

Hours_PS = Annual Standby Hours Plugged In

$$= \text{Hours}_P - \text{Hours}_C$$

$$= 3,233 \text{ hours}$$

Hours_US = Annual Standby Hours Unplugged

$$= 8760 - \text{Hours}_P$$

$$= 5,249 \text{ hours}$$

SP_base = Baseline Average Standby Power (W)

$$= 3.7 \text{ for non-networked, } 9.9 \text{ for networked}^{1225}$$

SP_EEp = Efficient Average Standby Power (W) with vehicle plugged in

$$= 3.8 \text{ for non-networked, } 5.5 \text{ for networked}^{1226}$$

SP_EEu = Efficient Average Standby Power (W) in no vehicle mode

$$= 2.5 \text{ for non-networked, } 4.1 \text{ for networked}^{1227}$$

$$\Delta \text{kWh per non-networked charger} = (((3,233 + 5,249) * 3.7) - (3,233 * 3.8 + 5,249 * 2.5)) / 1,000$$

$$= 5.8 \text{ kWh}$$

$$\Delta \text{kWh per networked charger} = (((3,233 + 5,249) * 9.9) - (3,233 * 5.5 + 5,249 * 4.1)) / 1,000$$

$$= 44.8 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta \text{kW} = \text{AveragekW} * \text{CF}$$

Where:

AveragekW = Average electric demand during standby.

$$\text{Hours}_S) / 1000$$

$$\text{Non-networked} = (((3.7-3.8) * 3,233/8,482) + ((3.7-2.5) * 5,249/8,482))/1,000$$

$$= 0.00069 \text{ kW}$$

¹²²⁴ Based on Northwest Power and Conservation Council, Regional Technical Forum updated workbook for Level 2 Electric Vehicle Charger version 3.1. See 'Level2EVChargers_v3_1.xlsm'.

¹²²⁵ INL charger testing and ENERGY STAR Market and Industry Scoping Report Electric Vehicle Supply Equipment (EVSE) September 2013 (source data is from INL).

¹²²⁶ 2026 ENERGY STAR QPL of Residential EVSE. Averaged Partial On Mode Input Power (W) and Idle Mode Input Power (W). See Level2EVChargers_EX QPL_3_23_26.xlsx

¹²²⁷ 2026 ENERGY STAR QPL of Residential EVSE. See Level2EVChargers_EX QPL_3_23_26.xlsx

$$\begin{aligned}\text{Networked} &= (((9.9-5.5) * 3,233/8,482) + ((9.9-4.1) * 5,249/8,482))/1,000 \\ &= 0.00144 \text{ kW}\end{aligned}$$

$$\begin{aligned}\text{CF} &= \text{Summer peak coincidence factor} \\ &= 100\%\end{aligned}$$

$$\begin{aligned}\text{Hours}_S &= \text{Annual Standby Hours} \\ &= 8760 - \text{Hours}_C \\ &= 8,482 \text{ hours}\end{aligned}$$

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-MSC-EVC-V03-270101

SUNSET DATE: 1/1/2030