

Iowa Energy Efficiency Statewide Technical Reference Manual Version 8.0

Volume 3: Nonresidential Measures

Final July 31, 2023

Effective: January 1, 2024

[INTENTIONALLY LEFT BLANK]

Table of Contents

Volume 1: Overview and User Guide

Volume 2: Residential Measures

Volume 3: Nonresidential Measures 11

3.1. Agricultural Equipment 11

- 3.1.1. Circulation Fans 11
- 3.1.2. Ventilation Fans 14
- 3.1.3. High Volume Low Speed Fans 17
- 3.1.4. Temperature Based On/Off Ventilation Controller 20
- 3.1.5. Automatic Milker Take Off 22
- 3.1.6. Dairy Scroll Compressor 24
- 3.1.7. Heat Lamp 27
- 3.1.8. Heat Reclaimer 29
- 3.1.9. Heat Mat 32
- 3.1.10. Grain Dryer 36
- 3.1.11. Live Stock Waterer 38
- 3.1.12. Low Pressure Irrigation 40
- 3.1.13. Variable Speed Frequency Drive for Dairy Vacuum Pump and Milking Machine 42
- 3.1.14. Dairy Plate Cooler 45
- 3.1.15. LED Grow Lights 48
- 3.1.16. Grain Bin Fan Aeration Controls 53
- 3.1.17. Dairy Refrigeration Tune-Up 59
- 3.1.18. ECM Ventilation Fan and Staging Controls 62
- 3.1.19. Grain Dryer Tune-Up 66

3.2. Hot Water 69

- 3.2.1. Low Flow Faucet Aerators 69
- 3.2.2. Low Flow Showerheads 77
- 3.2.3. Hot Water Heater 82
- 3.2.4. Controls for Central Domestic Hot Water 93
- 3.2.5. Pool Covers 95
- 3.2.6. Drainwater Heat Recovery 98

3.3. Heating, Ventilation, and Air Conditioning (HVAC) 103

- 3.3.1. Boiler 105
- 3.3.2. Furnace 109

Iowa Energy Efficiency Statewide Technical Reference Manual – Table of Contents

3.3.3.	Furnace Blower Motor.....	112
3.3.4.	Heat Pump Systems.....	115
3.3.5.	Geothermal Source Heat Pump.....	122
3.3.6.	Single-Package and Split System Unitary Air Conditioners.....	132
3.3.7.	Electric Chiller.....	138
3.3.8.	Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP).....	143
3.3.9.	Guest Room Energy Management (PTAC).....	149
3.3.10.	Boiler Tune-up.....	152
3.3.11.	Furnace Tune-Up.....	155
3.3.12.	Small Commercial Thermostats.....	158
3.3.13.	Variable Frequency Drives for HVAC Pumps and Cooling Tower Fans.....	162
3.3.14.	Variable Frequency Drives for HVAC Supply and Return Fans.....	166
3.3.15.	Duct Insulation.....	171
3.3.16.	Duct Repair and Sealing.....	177
3.3.17.	Chiller Pipe Insulation.....	184
3.3.18.	Hydronic Heating Pipe Insulation.....	188
3.3.19.	Shut Off Damper for Space Heating Boilers or Furnaces.....	193
3.3.20.	Room Air Conditioner (Removed 2021).....	197
3.3.21.	Room Air Conditioner Recycling.....	198
3.3.22.	Steam Trap Replacement or Repair.....	201
3.3.23.	Electric HVAC Tune-up.....	205
3.3.24.	Electric Chiller Tune-up.....	209
3.3.25.	Gas-Fired Heat Pump.....	212
3.3.26.	Variable Refrigerant Flow (VRF) Systems.....	216
3.3.27.	Demand Controlled Ventilation.....	219
3.4.	Lighting.....	224
3.4.1.	Compact Fluorescent Lamp – Standard (Removed 2021).....	226
3.4.2.	Compact Fluorescent Lamp – Specialty (Removed 2021).....	227
3.4.3.	LED Lamp Standard.....	228
3.4.4.	LED Lamp Specialty.....	233
3.4.5.	LED Fixtures.....	241
3.4.6.	T5 HO Fixtures and Lamp/Ballast Systems.....	248
3.4.7.	High Performance and Reduced Wattage T8 Fixtures and Lamps (Removed 2021).....	252
3.4.8.	Metal Halide (Removed 2021).....	253
3.4.9.	Commercial LED Exit Sign.....	254

Iowa Energy Efficiency Statewide Technical Reference Manual – Table of Contents

3.4.10.	LED Street Lighting.....	258
3.4.11.	LED Traffic and Pedestrian Signals (Removed 2021)	261
3.4.12.	Lighting Controls.....	262
3.4.13.	Daylighting Control (Removed 2020)	268
3.4.14.	Multi-Level Lighting Switch.....	269
3.5.	Miscellaneous.....	273
3.5.1.	Variable Frequency Drives for Process	273
3.5.2.	Clothes Washer.....	276
3.5.3.	Motors	281
3.5.4.	Forklift Battery Charger	286
3.6.	Food Service	291
3.6.1.	Dishwasher	291
3.6.2.	Commercial Solid and Glass Door Refrigerators & Freezers.....	300
3.6.3.	Pre-Rinse Spray Valve	305
3.6.4.	Infrared Upright Broiler	309
3.6.5.	Infrared Salamander Broiler	312
3.6.6.	Infrared Charbroiler.....	315
3.6.7.	Convection Oven	318
3.6.8.	Conveyor Oven	323
3.6.9.	Infrared Rotisserie Oven.....	327
3.6.10.	Commercial Steam Cooker	330
3.6.11.	Fryer.....	336
3.6.12.	Griddle	341
3.7.	Shell Measures	346
3.7.1.	Infiltration Control.....	347
3.7.2.	Foundation Wall Insulation	355
3.7.3.	Roof Insulation	360
3.7.4.	Wall Insulation.....	366
3.7.5.	Efficient Windows.....	371
3.7.6.	Insulated Doors.....	377
3.8.	Refrigeration	382
3.8.1.	LED Refrigerator Case Light Occupancy Sensor	382
3.8.2.	Door Heater Controls for Cooler or Freezer	385
3.8.3.	Efficient Motors for Walk-in and Display Case Coolers / Freezers	388

Iowa Energy Efficiency Statewide Technical Reference Manual – Table of Contents

3.8.4.	Night Covers for Open Refrigerated Display Cases.....	391
3.8.5.	Refrigerated Beverage Vending Machine.....	393
3.8.6.	Refrigerator and Freezer Recycling	396
3.8.7.	Scroll Refrigeration Compressor.....	405
3.8.8.	Strip Curtain for Walk-in Coolers and Freezers	409
3.8.9.	Ice Maker	412
3.8.10.	Efficient Motor Controls for Walk-In and Display Case Coolers/Freezers	417
3.8.11.	Adding Doors to Open Refrigeration Display Cases.....	420
3.8.12.	Refrigeration Economizers	425
3.8.13.	Auto-Closers for Walk-In Doors	428
3.8.14.	Refrigeration Tune-Up – Remote Condensing Unit.....	430
3.8.15.	Refrigeration Tune-Up – Self-Contained Unit.....	434
3.8.16.	Vending Machine Controllers	437
3.8.17.	Floating Head Pressure Controls	441
3.9.	Compressed Air	444
3.9.1.	Air Compressor with Integrated VSD.....	444
3.9.2.	High Efficiency Air Nozzles.....	447
3.9.3.	No Loss Condensate Drains	451
3.9.4.	Low Pressure Drop Filters.....	454
3.9.5.	Storage Receiver Tank	457

Volume 3: Nonresidential Measures

3.1. Agricultural Equipment

3.1.1. Circulation Fans

DESCRIPTION

Agricultural circulation fans are fans located in barns to provide air movement that helps to keep animals cool. Circulation fan efficiency is expressed as CFM¹/watt and is derived from the thrust efficiency ratio (TER) in pounds force per watt (lbf/W).

The measure applies to newly installed circulation fans or replacing an existing unit that reached the end of its useful life in agricultural applications.

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

In order for this characterization to apply, the efficient equipment must be certified by BESS Labs² with fan diameters above 12 inches that meet program minimum efficiency requirements.

Diameter of Fan (inches)	IPL Minimum Efficiency (CFM/Watt)
12-23	10.7
24-35	11.5
36-47	19.0
48+	21.5

Efficient fans are assumed to be governed by thermostatic on/off controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a new fan that does not meet program requirements. This characterization assumes that the baseline condition uses on/off thermostatic controls to automatically operate the fans above a designated temperature threshold and shut them off when temperature drops below setpoint.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.³

DEEMED MEASURE COST

Actual full installed costs may be used along with the following baseline cost assumptions:⁴

¹ Cubic Feet per Minute

² University of Illinois, Department of Agricultural and Biological Engineering. <http://bess.illinois.edu/>

³ Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 3,346 hours (see description of default run hours on following page); and rounded down to nearest whole year. Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.

⁴ Baseline full installed costs from Act on Energy Commercial Technical Reference Manual No. 2010-4. Cost for 12-23" diameter fans determined through extrapolation of costs for other fan sizes.

Diameter of Fan (inches)	Baseline Cost
12-23	\$375
24-35	\$450
36-47	\$525
48+	\$600

If actual costs are not available, assume an incremental total installed cost of \$150.⁵

LOADSHAPE

Loadshape NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_base - Watts_ee}{1000} * Hours * Nfans$$

Where:

Watts_base⁶ = Demand (W) of baseline fan

Diameter of Fan (inches)	Watts_base
12-23	366
24-35	615
36-47	810
48+	1358

Watts_ee⁷ = Demand (W) of efficient fan

Diameter of Fan (inches)	Watts_ee
12-23	298
24-35	440
36-47	529
48+	993

Hours = Actual hours of operation. Typically, the fans will be operated above certain temperature thresholds, and therefore the operating hours can be reasonably estimated using the Ag Ventilation Operating Hours Calculator if temperature setpoints are known. If not, the following table⁸ can be used to establish operating hours by facility type (hog, poultry, or dairy). For dairy facilities the typical temperature setpoint can be assumed to be 67°F, for poultry and hog facilities it can be assumed to be 65°F and 60°F, respectively, as these are the recommended temperatures above which comfort cooling should be

⁵ Act on Energy Commercial Technical Reference Manual No. 2010-4.

⁶ BESS fan database downloaded on 7/1/2015. Average watts from models below standard. AgCirculation Fans.xls

⁷ BESS fan database downloaded on 7/1/2015. Average watts from models above standard. AgCirculation Fans.xls

⁸ Based on NCDC US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa. For more information on the weighting, see: "Ag Op Hours_2023.xlsx".

provided for livestock.⁹

Facility Type	Annual Hours of Operation
Hog	3,600
Poultry	3,072
Dairy	2,832
Unknown/Other	3,346

Nfans = Number of circulation fans
 = Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{base} - Watts_{ee}}{1000} * CF * Nfans$$

Where:

CF = Summer Peak Coincidence Factor
 = 100%¹⁰

NATURAL GAS ENERGY 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: NR-AGE-CIRC-V05-240101

SUNSET DATE: 1/1/2028

⁹ Dairy Farm Energy Management Guide, Southern California Edison February, 2004. The guide recommends controlling fans in order to provide maximum ventilation as necessary at 72°F and above due to heat stress concerns on cows at and above that temperature. The 67°F balance point was developed assuming a 5°F temperature band, assuming the interior temperature of the barn will be greater than that outside due to internal heat gains.

¹⁰ Industrial Ventilation CF from eQuest.

3.1.2. Ventilation Fans

DESCRIPTION

Agricultural ventilation fans provide ventilation air to keep animals cool. Fan efficiency is expressed as CFM/watt and is derived from the thrust efficiency ratio (TER) in pounds force per watt (lbf/kW).

The measure applies to newly installed ventilation fans or replacing an existing unit that reached the end of its useful life in agricultural applications.

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

In order for this characterization to apply, the efficient equipment must be certified by BESS Labs¹¹ with fan diameters above 14 inches that meet program minimum efficiency requirements.

Diameter of Fan (inches)	IPL Minimum Efficiency (CFM/Watt) at (0.05 SP ¹²)
14-23	10.1
24-35	13.5
36-47	17.4
48+	20.3

Efficient fans are assumed to be governed by thermostatic on/off controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a new fan that does not meet program requirements. This characterization assumes that the baseline condition uses on/off thermostatic controls to automatically operate the fans above a designated temperature threshold and shut them off when temperature drops below setpoint.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6.5 years.¹³

DEEMED MEASURE COST

Actual full installed costs may be used along with the following baseline cost assumptions:¹⁴

Diameter of Fan (inches)	Baseline Cost
14-23	\$375
24-35	\$450
36-47	\$525
48+	\$600

¹¹ University of Illinois, Department of Agricultural and Biological Engineering. <http://bess.illinois.edu/>

¹² Static Pressure in units of inches of water

¹³ Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 5,305 hours (see description of default run hours on following page). Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.

¹⁴ Baseline full installed costs from Act on Energy Commercial Technical Reference Manual No. 2010-4. Cost for 14-23" diameter fans determined through extrapolation of costs for other fan sizes.

If actual cost not available, assume an incremental total installed cost of \$150.¹⁵

LOADSHAPE

Loadshape NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_base - Watts_ee}{1000} * hours * Nfans$$

Where:

Watts_base¹⁶ = Demand (W) of baseline fan

Diameter of Fan (inches)	Watts_base (0.05 SP)
14-23	382
24-35	550
36-47	879
48+	1353

Watts_ee¹⁷ = Demand (W) of efficient fan

Diameter of Fan (inches)	Watts_ee (0.05 SP)
14-23	304
24-35	383
36-47	565
48+	1041

Hours = Actual hours of operation. Typically, the fans will be operated in a staged fashion such that only a fraction of total fans are operating in conditions that do not require maximum installed capacity. Accordingly, effective full load hours (EFLH) should be determined based on operating schedule and considering factors such as number of fans, stages, and temperature band definitions. If this information is unavailable, the table below may be used to reasonably estimate EFLH for hog, poultry, and dairy facilities, based on typical control schedules.¹⁸

Facility Type	Annual EFLH
Hog	5,570
Poultry	5,020
Dairy	4,771

¹⁵ Act on Energy Commercial Technical Reference Manual No. 2010-4.

¹⁶ BESS fan database downloaded on 7/1/2015. Average watts from models below standard (minimum efficiency requirement detailed in the efficient equipment definition). For more detail, see: "AgVentilationFans.xls"

¹⁷ BESS fan database downloaded on 7/1/2015. Average watts from models above standard (minimum efficiency requirement detailed in the efficient equipment definition). For more detail, see: "AgVentilationFans.xls"

¹⁸ See "Ag Op Hours_2023.xlsx" workbook for a complete description and derivation of default operating hours. EFLH based on NCDC US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa.

Facility Type	Annual EFLH
Unknown/Other	5,305

Nfans = Number of ventilation fans
 = Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{base} - Watts_{ee}}{1000} * CF * Nfans$$

Where:

CF = Summer Peak Coincidence Factor
 = 100%¹⁹

NATURAL GAS ENERGY 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: NR-AGE-VENT-V04-240101

SUNSET DATE: 1/1/2028

¹⁹ Industrial Ventilation CF from eQuest.

3.1.3. High Volume Low Speed Fans

DESCRIPTION

High volume low speed (HVLS) fans provide air circulation to improve thermal comfort and indoor air quality. The measure applies to HVLS fans that are replacing multiple less efficient conventional fans in agricultural applications. This measure assumes single-speed, steady state operation for both baseline and efficient equipment.

This measure applies to the following program types: RF, NC.

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 fan with a diameter above 16 feet that meets program minimum efficiency requirements.

DEFINITION OF BASELINE EQUIPMENT

As a retrofit measure, the actual existing conditions are taken as baseline. The number and wattage of the existing fans shall be used to define baseline energy consumption. As a new construction measure, baseline is taken as the total operating wattage of conventional fans required to match the flow rate (CFM) rating of the efficient equipment.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.²⁰

MEASURE COST

As a retrofit measure, the actual installation cost should be used for screening and reporting purposes.

For a new construction measure, actual full installed costs may be used along with the following baseline cost assumptions:²¹

Diameter of Fan (feet)	Baseline Cost
16-17.9	\$1210
18-19.9	\$1460
20-23.9	\$1840
24 +	\$2090

If actual costs are unavailable for new construction, the incremental measure costs are as follows:²²

Diameter of Fan (feet)	Incremental Cost
16-17.9	\$4100
18-19.9	\$4130
20-23.9	\$4190
24 +	\$4230

²⁰ Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 3,346 hours (see description of default run hours on following page); and rounded down to nearest whole year. Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.

²¹ Baseline full installed costs linearly extrapolated using cost data from the Illinois ActOnEnergy TRM No. 2010-4. Midpoints were used to establish a single cost for each fan diameter category. Costs rounded up to the nearest \$10.

²² Incremental costs linearly extrapolated using cost data from the Illinois ActOnEnergy TRM No. 2010-4. Midpoints were used to establish a single cost for each fan diameter category. Costs rounded up to the nearest \$10.

LOADSHAPE

Loadshape– NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{\sum(N_{base} * Watts_{base}) - \sum(N_{ee} * Watts_{ee})}{1000} * Hours$$

Where:

- N_{base} = Number of baseline (conventional) fans being replaced (of equivalent wattage)
= Actual (for Retrofit projects). For new construction projects, the number of baseline fans should be set equivalent to the number of HVLS fans being installed.
- Watts_{base} = Operating demand (W) of baseline fan
=Actual (Retrofit). For new construction projects refer to the New Construction HVLS connected load savings table below.
- N_{ee} = Number of efficient fans installed (of equivalent wattage)
= Actual
- Watts_{ee} = Operating demand (W) of efficient fan
= Actual (Retrofit). For new construction projects refer to the New Construction HVLS connected load savings table below.

New Construction HVLS Connected Load Savings²³

Diameter of Fan (feet)	Watts_base	Watts_ee
16-17.9	4497	761
18-19.9	5026	850
20-23.9	5555	940
24 +	6613	1119

- Hours = Actual hours of operation. Typically, the fans will be operated above certain temperature thresholds, and therefore the operating hours can be reasonably estimated using the “Ag Ventilation Operating Hours Calculator,” if temperature setpoints are known. If not, the following table²⁴ can be used to establish operating hours. For dairy facilities, the typical temperature setpoint can be assumed to be 67°F, for poultry and hog facilities it can be assumed to be 65°F and 60°F, respectively, as these are the recommended temperatures above which comfort cooling should be provided for

²³ KEMA 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, Group 1 Programs, Volume 2 (Table 17). Typically, the number of baseline conventional circulation fans the HVLS fan is off-setting is not a one for one replacement scenario. Due to their more efficient design, a single HVLS fan can move and displace as much air as multiple conventional circulation fans. The baseline wattage represents the equivalent quantity of baseline fans and their wattages to match that of a single HVLS fan.

²⁴ See “Ag Op Hours_2023.xlsx” workbook for a complete description and derivation of default operating hours. Hours based on NCDC US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa.

livestock.²⁵

Facility Type	Annual Hours of Operation
Hog	3,600
Poultry	3,072
Dairy	2,832
Unknown/Other	3,346

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\sum(-N_{base} * Watts_{base}) - \sum(N_{ee} * Watts_{ee})}{1000} * CF$$

Where:

CF = Summer Peak Coincidence Factor
 = 100%²⁶

NATURAL GAS ENERGY 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: NR-AGE-HVLS-V04-240101

SUNSET DATE: 1/1/2028

²⁵ Dairy Farm Energy Management Guide, Southern California Edison February, 2004. The guide recommends controlling fans in order to provide maximum ventilation as necessary at 72°F and above due to heat stress concerns on cows at and above that temperature. The 67°F balance point was developed assuming a 5°F temperature band, assuming the interior temperature of the barn will be greater than that outside due to internal heat gains.

²⁶ Industrial Ventilation CF from eQuest.

3.1.4. Temperature Based On/Off Ventilation Controller

DESCRIPTION

Temperature based on/off ventilation controllers on agricultural ventilation fans can reduce fan run times and save energy. This measure applies to ventilation controllers installed on existing ventilation fans. Although the complexity and intelligence of available controls can vary widely, this characterization claims savings strictly from the on/off control of ventilation fans based on temperature. Additional savings may result from highly intelligent controls that automate heating and cooling stages or multiple modes of ventilation. Savings from such controls are best handled as a custom calculation because commissioning is required to optimize functionality based on unique site and design considerations.

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, a new ventilation controller is installed on new or existing ventilation fans. Temperature based on/off control is considered industry standard practice for new ventilation systems and therefore this characterization only applies to retrofit situations.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a fan that does not have a ventilation controller. It is assumed that fans are operated continuously in their maximum capacity from the first hot day in spring to last hot day in fall. For hog operations, “hot” is defined as temperatures above 60°F. For poultry operations, “hot” is defined as temperatures above 65°F. And for dairy operations, “hot” is defined as temperatures above 70°F. Additionally, it is assumed that for hog facilities, 30% of fans operate continuously, year-round to meet minimum ventilation requirements. For dairy facilities, 10% of fans are assumed to operate continuously.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6.5 years.²⁷

DEEMED MEASURE COST

As a retrofit measure, the actual installation cost should be used for screening and reporting purposes.

LOADSHAPE

Loadshape NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{fan}}{1000} * (Hours_{control})$$

²⁷ Average motor life 35,000 hours as estimated by U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3. The measure life was then derived by dividing by the average ventilation fan run time by the default of unknown/other farm commodity, 5,305 hours.

Iowa Energy Efficiency Statewide Technical Reference Manual—3.1.4 Temperature Based On/Off Ventilation Controller

Where:

Watts_{fan} = Total wattage of controlled fans
 = Actual - If unknown, the following table can be used to estimate:²⁸

Diameter of Fan (inches)	Watts _{fan} (0.05 SP)
14-23	382
24-35	550
36-47	879
48+	1353

Hours_{control} = Reduction in fan run hours due to controller²⁹

Facility Type	Hours _{control}
Hog	737
Poultry	651
Dairy	58
Unknown/Other	632

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A - Assume no change in fan operation during summer coincident peak period, as fans will be running regardless of thermostat controls and therefore no savings during peak period.

NATURAL GAS ENERGY 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: NR-AGE-VCON-V03-240101

SUNSET DATE: 1/1/2026

²⁸ BESS fan database downloaded on 7/1/2015. Average watts from models considered baseline. AgVentilationFans.xls

²⁹ See "Ag Op Hours_2023.xlsx" workbook for a complete description and derivation of default operating hours. Hours based on US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). Additional factors are incorporated into the analysis such as fan temperature settings and staging's. The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa.

3.1.5. Automatic Milker Take Off

DESCRIPTION

This measure characterizes the energy savings for the installation of automatic milker takeoffs on dairy milking vacuum pump systems. Automatic Milker Takeoff measure reduces energy use by shutting off the milking vacuum pump suction once a minimum flowrate has been achieved.

Because automatic milker takeoffs have been standard equipment in new milk parlors since 1995,³⁰ this measure is limited to existing dairy parlors for which no size upgrade or other vacuum system improvement has happened.

DEFINITION OF BASELINE EQUIPMENT

The baseline is an existing dairy parlor with no previously existing automatic milker takeoff and no plans to increase size and or make any other vacuum pump improvements.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a milker takeoff is 10 years.³¹

DEEMED MEASURE COST

Retrofit measure, actual costs will be used.

LOADSHAPE

Loadshape NRE11 – Nonresidential Agriculture

Algorithm

CALCULATION OF SAVINGS

Electric Energy Savings:

$$\Delta kWh = kWh/cow/milking * Nmilings * Ncows$$

Where:

- kWh/cow/milking = 50³²
- Nmilings = Number of milkings per day
= Actual, if unknown use 2³³
- Ncows = Number of milking cows per farm

³⁰ Reinemann, D. "Milking Facilities for the Expanding Dairy" presented at the 1995 conference of the WVMA. University of Wisconsin-Madison, Department of Agricultural Engineering Milking Research and Instruction Lab.

³¹ Idaho Power Demand Side Management Potential Study – Volume II Appendices, Nexant, 2009

³² Alliant's Global Energy Partners impact calculations in DSM Tracking, 2006, and in agreement with IPL Energy Efficiency Programs 2009 Evaluation, KEMA. Appendix F Program Evaluations Group 1, Vol 2.

³³ Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List; Agricultural: Variable Frequency Drives-Dairy, FY2012, v1.2. Pre- and post-power meter data for five sites were used to establish RTF energy savings and the raw data used to generate load profiles showed, on average, two milkings per day. For further detail on the corroboration of this source, please see the 2016 Pennsylvania TRM.

= Actual; if unknown use 140³⁴

SUMMER COINCIDENT PEAK DEMAND SAVINGS:

$$\Delta kW = \frac{\Delta kWh}{FLH} \times CF$$

Where:

- FLH = Full Load Hours
= 2,703³⁵
- CF = Coincidence Factor
= 79.3%³⁶

NATURAL GAS ENERGY 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: NR-AGE-AMTO-V05-240101

SUNSET DATE: 1/1/2028

³⁴ Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397. Average number of cows per farm = 223,579 cows / 1,592 farms = 140

³⁵ The full load hours are based on an average number of milkings per day of two, and assumptions on the average hours per milking of 3.7 hours, with milking occurring 365.25 days a year. Source Milking System Air Consumption When Using a Variable Speed Vacuum Pump. Paper Number: 033014 An ASAE Meeting Presentation. July 2003

³⁶ Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls

3.1.6. Dairy Scroll Compressor

DESCRIPTION

This measure characterizes the energy savings from the installation of an efficient scroll compressor in place of a reciprocating compressor for dairy parlor milk refrigeration.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure is a more efficient scroll compressor from 1 to 10 HP replacing an existing reciprocating compressor with the same horsepower for dairy parlor milk refrigeration.

DEFINITION OF BASELINE EQUIPMENT

The baseline is the existing reciprocating compressor for dairy parlor milk refrigeration.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.³⁷

DEEMED MEASURE COST

As a retrofit measure, the actual installation and equipment costs are used.

LOADSHAPE

Loadshape NRE01 - Non-Residential Refrigeration - Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right) * Gal * Days_{yr} * Specific_{heat} * Density_{milk} * \Delta T * \frac{1}{1000} * N_{Cows}$$

Where:

EER_{Base} = Cooling efficiency of existing compressor in Btu/watt-hour
 = Actual, if unknown use values from table below³⁸

EER_{ee} = Cooling efficiency of efficient scroll compressor in Btu/watt-hour
 = Actual, if unknown use values from table below³⁹

³⁷ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, "Effective/Remaining Useful Life Values", California Public Utilities Commission, February 4, 2014

(http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx)

³⁸ Efficiency Vermont TRM User Manual No. 2014-87 and spreadsheet compressor efficiency analysis EVT Refrigeration 2013.xlsx In 2013 data from compressor manufacturers was downloaded to calculate average efficiency available for various categories of compressors. These average values are used for baseline efficiency.

³⁹ Efficiency Vermont TRM User Manual No. 2014-87 and spreadsheet compressor efficiency analysis EVT Refrigeration 2013.xlsx In 2013 data from compressor manufacturers was downloaded to calculate average efficiency available for various categories of compressors. These average values are used for baseline efficiency.

Medium Temperature			
Baseline and Qualifying EER			
Condensing temp 90°F, Evap Temp 20°F			
Capacity Bins in BTU/Hr	HP equivalent	Average EERbase	Average EERee
0-7500	1	8.14	9.03
7500-14999	2	9.28	10.86
15000-22499	3	10.64	11.83
22500-29999	4	11.18	12.15
30000-37499	5	11.12	12.39
37500-44999	6	11.74	12.70
45000-52499	7	11.68	12.52
52500-59999	8	12.54	13.12
60000-67499	9	12.46	13.13
67500-75000	10	11.44	12.37

Gal = Gallons of milk produced by one cow in a day

$$= 6^{40}$$

Days_{yr} = Number of days per year

$$= 365.25$$

Specific_{heat} = Specific heat of milk in Btu/lb-°F

$$= 0.93^{41}$$

Density_{milk} = Density milk in lb/gal

$$= 8.6$$

ΔT = Required change in temperature (with precooler) in °F

$$= 19^{42}$$

Required change in temperature (without precooler) in °F

$$= 59^{43}$$

1000 = Conversion factor from watts to kilowatts

N_{Cows} = Number of cows

$$= \text{Actual, if unknown use 140 cows}^{44}$$

For example, for a 5 HP efficient scroll compressor (with precooler) replacing an existing reciprocating compressor, serving 90 cows:

$$\begin{aligned} \Delta kWh &= (1/11.12 - 1/12.39) * 6 * 365.25 * 0.93 * 8.6 * 19 * 1/1000 * 90 \\ &= 276.3 kWh \end{aligned}$$

⁴⁰ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2

⁴¹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2

⁴² IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

⁴³ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

⁴⁴ Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397. Average number of cows per farm = 223,579 cows / 1,592 farms = 140

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh}{FLH} \times CF$$

Where:

FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are 3910 hours for medium temperature applications.⁴⁵

CF = System Peak Coincidence Factor. Assume non-residential average of 96.4%

For example, for a 5 HP efficient scroll compressor (with precooler) replacing an existing reciprocating compressor, serving 90 cows:

$$\begin{aligned} \Delta kW &= (276.3/3910) * 0.964 \\ &= 0.0681 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY 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: NR-AGE-SCROL-V04-210101

SUNSET DATE: 1/1/2021*

* 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.

⁴⁵ Based on run time estimates from “Performance Standards for Walk-In Refrigerator and Freezer Systems,” AHRTI Report No. 09002-01, by Bryan R. Becker, et al., January 2012, Tables 30-33.

3.1.7. Heat Lamp

DESCRIPTION

This measure characterizes the energy savings from the installation of a reduced wattage heat lamp to heat infant animals (especially pigs) during the summer months.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure is the reduced wattage heat lamp must be less than or equal to 125 watts.

DEFINITION OF BASELINE EQUIPMENT

The baseline is assumed to be a standard wattage heat lamp of 175 watts.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 1 year.⁴⁶

DEEMED MEASURE COST

Incremental cost is assumed to be \$0.⁴⁷

LOADSHAPE

Loadshape C04 - Nonresidential Electric Heating

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{W_{Base} - W_{Eff}}{1000} * Hours * N_{Units}$$

Where:

W_{Base} = Wattage of baseline heat lamp
= 175 watts⁴⁸

W_{eff} = Wattage of reduced wattage heat lamp
= Actual if known, otherwise assume 125 watts⁴⁹

⁴⁶ The one year measure life is based on an expected lamp lifetime of approximately 5,000 hours

⁴⁷ Internet search on <http://www.qcsupply.com/> indicates no cost differential between 125 w and 175 w bulbs

⁴⁸ The 175 watt baseline is based on standard practice based on discussions with IPL's program manager Dave Warrington on October 14, 2015.

⁴⁹ The 125 watt bulb replaces a 175 watt bulb, baseline is based on discussions with IPL's program manager Dave Warrington on October 14, 2015

Hours = Annual heat lamp operating hours⁵⁰
 = 5,105 hours

1,000 = Conversion factor from watts to kilowatts
 = 1,000

Nunits = Number of units installed
 = Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer coincident peak demand savings for heating measures

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: NR-AGE-HTLP-V02-210101

SUNSET DATE: 1/1/2027

⁵⁰ 5,105 hours for the default value is based on: Calculation method from Iowa State University farm manager (Ben Drescher): "At minimum I'd say they are on 24-7 from Oct-March, March-May 12 hours a day, June-September 8 hours a day. You'd also take off for power washing, etc., so if you had a 24 day turn in a farrowing room you'd run them for 21 days and turn the room subtract 3 days from x 15 turns a year - resulting in 5120 hours." 5120 is rounded up. Actual calculation results in 5,105 hours. Additional information to support this hour value is an email sent 10/23/15. "FW: Heat lamp bulbs". Itron benchmarked the HOU with their our analysis which resulted in 5,109 hours: 30.42 days/month; 3 months (summer) run 33% of time; 6 months run 50% of time; 3 months (winter) run full time.

3.1.8. Heat Reclaimer

DESCRIPTION

This measure characterizes the energy savings from the installation of a milk house heat reclaimer to reduce waste heat from milk cooling compressor. The heat reclaimer captures the waste heat from the compressors being removed from the milk.

This measure applies to the following market: RF.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are new equipment must be of one of the following brands: Century-Therm, FreHeater, Heat Bank, Sunset, Superheater and Therma-Stor. Also must have an electric water heater to achieve electric savings.

DEFINITION OF BASELINE EQUIPMENT

The baseline is milk cooling compressor and electric water heater; no existing heat reclaimer installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a heat reclaimer is 15 years.⁵¹

DEEMED MEASURE COST

As a retrofit measure, the actual installation cost should be used.

LOADSHAPE

Loadshape C04 - Nonresidential Electric Heating

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\text{Heat Available} = \text{Lbs of Milk} * C_{P,\text{Milk}} * \Delta T_{\text{Milk}} * \text{Days}$$

Where:

- Lbs of Milk = The pounds of milk produced per day per cow that needs to be cooled
= 51.6 lbs of milk per cow per day⁵²
- $C_{P,\text{Milk}}$ = Specific heat of milk
= 0.93 Btu/(lb-°F)
- ΔT_{Milk} = Change in milk temperature (°F)

⁵¹ PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report", August 25, 2009

⁵² The pounds of milk produced per cow per day is based on an average cow producing 6 gallons of milk per day, with each gallon of milk weighing approximately 8.6 pounds (6 gallons of milk per cow per day x 8.6 lbs = 51.6 lbs of milk per cow per day).

- = 59°F without precooler installed; 19°F with precooler installed
- Days = Number of milking days per year
= 365 days
- Heat Available = 1,033,422 Btu per cow per year without precooler
= 332,797 Btu per cow per year with precooler

$$Heat\ Storage = Hot\ Water * P_{Water} * C_{P,Water} * \Delta T_{Water} * Days$$

Where:

- Hot Water = Gallons of hot water needed per cow per day
= 2.2 gallons per cow per day
- P_{Water} = Density of water
= 8.33 lbs/gallon
- $C_{P,Water}$ = Specific heat of water
= 1 Btu/(lb-°F)
- ΔT_{Water} = Change in water temperature between the incoming water and the hot water leaving the hot water heater
= 70°F
- Heat Storage = 468,229 Btu per cow per year

These equations, for the reclaimable heat available from the milk (Heat Available) and for the heat required for the hot water needs for the dairy (Heat Storage), reveal that the heat available from the milk limits the usable heat when a precooler is installed. In the absence of a precooler, the heat storage limits the usable heat, as shown in Table 1 below.

Table 1 - Reclaimable Heat

Case	Btu/yr	Limitation
No Precooler	468,229	Heat Storage
With Precooler	332,797	Heat Available

$$\Delta kWh\ per\ cow = Reclaimable\ Heat * \left(\frac{1}{EF_{elec}} \right) / 3,412$$

Where:

- EF_{elec} = Energy factor of the electric water heater
= Actual, if unknown use 0.90⁵³
- Reclaimable Heat = Values shown in Table 1 in Btu per cow per year
- 3,412 = Btu to kWh electric conversion factor

⁵³ Entered from application form; default value based on: IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

Table 2 – Heat Reclaimer Savings

Case	kWh/Cow
No precooler installed	152.5
Precooler installed	108.4

This method requires the program to collect information on existing precooler installation. When rebating a precooler and heat reclaimer at the same time, KEMA recommends that IPL follows the installation order discussed above. This measure should be limited to electric water heaters only. Customers with propane or natural gas water heaters will not achieve any electric or natural gas savings for this measure.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

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: NR-AGE-HTRE-V05-240101

SUNSET DATE: 1/1/2028

3.1.9. Heat Mat

DESCRIPTION

This measure characterizes the energy savings from the replacement of heat lamps with heat mats. Heat lamps in farrowing barns direct heat downward to keep the piglets warm. Replacing heat lamps with hog heat mats reduces the amount of heat lost to the ambient air by heating directly beneath the piglets. Farrowing heat mats have a lower wattage draw than the typical heat lamp setup, which results in annual energy savings.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are the reduced wattage heat mat must be less than or equal to 90 watts for a single mat (typically sized at 14" x 60") and then less than or equal to 180 watts for a double mat (typically sized at 24" x 60"). Additionally, the heat mats must replace an existing heat lamp system.

DEFINITION OF BASELINE EQUIPMENT

The baseline is standard wattage heat lamps.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a heat mat is 5 years.⁵⁴

DEEMED MEASURE COST

Incremental cost is assumed to be \$225.⁵⁵

LOADSHAPE

Loadshape C04 - Non-Residential Electric Heating

Algorithm

CALCULATION OF ENERGY SAVINGS⁵⁶

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = [(Mats_{Single} * Savings_{SingleMat}) + (Mats_{Double} * Savings_{DoubleMat})] - Controller * Controller Impact$$

Where:

- Mats_{Single} = Number of single mats at 90 watts or less, actual
- Mats_{Double} = Number of single mats at 180 watts or less, actual
- Savings_{SingleMat} = Default energy savings per single mat, dependent on baseline heat lamp (kWh/mat)

⁵⁴Professional judgement

⁵⁵ Cost data comes from Hog Hearth Heat Mat Calculator "Rev 03 02 14 Copy of Electrical costs 5 ft heat mats.xls" . Spreadsheet was shared with Cadmus but requested that document not be released publicly.

⁵⁶All variable values come from: IPL Custom Farrowing Heat Mat Calculator. For derivation of the default energy savings per mat and per baseline heat lamp, please see: "IA TRM_Heat Mat Analysis_June 2020.xlsx".

Baseline Heat Lamp	kWh Savings _{SingleMat}
175 watts	657
125 watts	338

Savings_{DoubleMat} (kWh/mat) = Default energy savings per double mat, dependent on baseline heat lamp

Baseline Heat Lamp	kWh Savings _{DoubleMat}
175 watts	1,327
125 watts	817

Controller = Number of Controllers, actual

Controller Impact = 383 kWh/usage per controller

Custom calculation for heat mats shown below, otherwise use deemed values listed above.

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

Where:

$$kWh_{Base} = \frac{Crates_{Total} * Hours_{Yr} * Fixture_{Crate} * Lamp_{Fixture} * Wattage_{Lamp}}{1000 \frac{Watts}{kWh}}$$

$$kWh_{EE} = Controller + Crates_{single} + Crates_{double}$$

$$Controller = \frac{Controller_{Adv} * Hours_{yr} * Rooms * [(MSU_{Room} * MSU_{Wattage})]}{1000 \frac{Watts}{kWh}}$$

$$Crates_{single} = \frac{[(Crates_{Single-Row} * Single_{Wattage} * Single_{Mat} * Rows * Hours_{yr} * Rooms)]}{1000 \frac{Watts}{kWh}}$$

$$Crates_{double} = \frac{[(Crates_{Double-Row} * Double_{Wattage} * Double_{Mat} * Rows * Hours_{yr} * Rooms)]}{1000 \frac{Watts}{kWh}}$$

$$Crates_{Total} = (Crates_{Single-Row} + Crates_{Double-Row}) * Rows * Rooms$$

Where:

Crates_{Total} = Number of crates

= 234

Hours_{Yr} = Annual hours of operation

=5,105 hours⁵⁷

Fixture_{Crate} = Number of heat lamp fixtures per crate

=Actual. If unknown, use 1.25

⁵⁷ While heat mat hours do vary from heat lamps slightly, the savings assumptions match heat lamp hours for consistency. Calculation method from Iowa State University farm manager (Ben Drescher): "At minimum I'd say they are on 24-7 from Oct-March, March-May 12 hours a day, June-September 8 hours a day. You'd also take off for power washing, etc., so if you had a 24 day turn in a farrowing room, you'd run them for 21 days and turn the room subtract 3 days from x 15 turns a year - resulting in 5120 hours." Cadmus did not round data and estimated 5,105 hours. Email sent 10/23/15. "FW: Heat lamp bulbs". Itron benchmarked the HOU with their own analysis which resulted in 5,109 hours: 30.42 days/month; 3 months (summer) run 33% of time; 6 months run 50% of time; 3 months (winter) run full time.

Lamp _{Fixture}	= Number of heat lamps per fixture =1
Wattage _{Lamp}	= Wattage of heat lamp = Actual. If unknown, use 175 watts
1000 Watts/kW	= Constant, conversion factor for watts to kW
Controller _{Adv}	= Controller advantage =1
Rooms	= Number of rooms per farrowing barn = Actual. If unknown, use 9
MSU _{Room}	= Number of master sensor units (MSU) per room =1
MSU _{Wattage}	= Wattage of master sensor unit =75W
Crate _{Single-Row}	= Number of single crates per row = Actual. If unknown, use 1
Single _{Wattage}	= Wattage of a 14" x 60" farrowing heat mat = 90W
Single _{Mat}	= Number of 14" x 60" farrowing heat mats per single crate = Actual. If unknown, use 1
Rows	= Number of rows per room = Actual. If unknown, use 2
Crate _{Double-Row}	= Number of Double Crates per Row = Actual. If unknown, use 12
Double _{Wattage}	= Wattage of a 24" x 60" farrowing heat mat =180W
Double _{Mat}	= Number of a 24" x 60" farrowing heat mat =0.5

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer coincident peak demand savings for heating measures

NATURAL GAS ENERGY 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: NR-AGE-HTMT-V04-240101

SUNSET DATE: 1/1/2027

3.1.10. Grain Dryer

DESCRIPTION

This measure characterizes the energy savings from the replacement of an existing, old grain dryer with a new grain dryer. Electric savings are achieved by replacing old grain dryers with new grain dryers that operate more efficiently due to design improvements, increased throughput, capacity, production, and reduced hours of operation.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure is the Installation of a new electric grain dryer. Bushels per hour must be provided by the manufacturer, rated at 5 points of moisture removal per bushel. Gas dryers and those with capacities larger than 5,000 bushels/hour must go through the Custom Rebate program,

DEFINITION OF BASELINE EQUIPMENT

The baseline older grain dryers and is the same for retrofit, market opportunity, and new construction as old or refurbished grain dryers are available on the market.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a grain dryer is 15 years.⁵⁸

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown the capital cost for this measure is assumed to be the values as summarized in the table below.⁵⁹

Tier (bushels per hour)	Tier (annual bushels)	Average Incremental cost
< 500	< 170,000	\$20,000
≥ 500 and < 1000	≥ 170,000 and < 330,000	\$30,000
≥ 1000 and < 2000	≥ 330,000 and < 670,000	\$40,000
≥ 2000 and < 3500	≥ 670,000 and < 1,200,000	\$70,000
≥ 3500 and ≤ 5000	≥ 1,200,000 and ≤ 1,700,000	\$100,000

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Bushels_{yr} * (kWh_{Bushel\ old} - kWh_{Bushel\ new})$$

Where:

$Bushels_{yr}$ = Number of average bushels dried per year

⁵⁸ Estimate based on professional judgment

⁵⁹ Source: Version 9_9_15 Formatted Grain Dryer Prescriptive.xls

= Actual, if unknown use table:⁶⁰

Savings Tier (Bushels/hr) from manufacturer	Savings Tier (Bushels/yr)	Average Bushels/yr
< 500	< 170,000	85,000
≥ 500 and < 1,000	≥ 170,000 and < 330,000	225,000
≥ 1,000 and < 2,000	≥ 330,000 and < 670,000	400,000
≥ 2,000 and < 3,500	≥ 670,000 and < 1,200,000	900,000
≥ 3,500 and ≤ 5,000	≥ 1,200,000 and ≤ 1,700,000	1,400,000

$kWh_{Bushel\ old}$ = kWh usage per bushel for an old grain dryer
= 0.075⁶¹

$kWh_{Bushel\ new}$ = kWh usage per bushel for a new grain dryer
= 0.035⁶²

SUMMER COINCIDENT PEAK DEMAND SAVINGS

This technology does not provide peak demand savings; grain drying operations do not run during peak summer months.

NATURAL GAS ENERGY 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: NR-AGE-GNDR-V02-200101

SUNSET DATE: 1/1/2025

⁶⁰ Alliant Energy Custom Rebate project data from 2012-2014

⁶¹ Alliant Energy Custom Rebate project data from 2012-2014

⁶² Alliant Energy Custom Rebate project data from 2012-2014

3.1.11. Live Stock Waterer

DESCRIPTION

Automatic waterers consist of an insulated base and a heated bowl that automatically fills with water from a pressurized line. A float-operated valve controls the level of the water in the bowl. A thermostat regulates the water temperature in the bowl.

This measure applies to the replacement of electric open waterers with equivalent herd size watering capacity of the old unit.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is an electrically heated thermally insulated waterer with minimum 2 inches of insulation. A thermostat is required on units with heating elements greater than or equal to 250 watts.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be an electric open waterer with sinking or floating water heaters that have reached the end of useful life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.⁶³

DEEMED MEASURE COST

Actual costs may be used if associated baseline costs can also be estimated for the application. If actual costs are unknown, assume an incremental capital cost of \$535.⁶⁴

LOADSHAPE

Loadshape C04 - Nonresidential Electric Heating

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{kWh}{waterer} * N_{Units}$$

Where:

kWh/Waterer = 1104⁶⁵

N_{Units} = Number of waterers installed per farm

⁶³ Act on Energy Commercial Technical Reference Manual No. 2010-4. Typical warranty on waterers is 10 years.

⁶⁴ Based on internet review of leading manufacturers, 03/2023.

⁶⁵ Alliant's Global Energy Partners impact calculations in DSM Tracking, 2006 and is in agreement with IPL 2014 EEP filing

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer coincident peak demand savings for heating measures

NATURAL GAS ENERGY 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: NR-AGE-LSWT-V03-240101

SUNSET DATE: 1/1/2027

3.1.12. Low Pressure Irrigation

DESCRIPTION

This measure characterizes the energy savings from the replacement of an existing irrigation system with a more energy-efficient system. Low pressure nozzles are used to decrease the necessary pump pressure.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure is a new irrigation system that reduces the pump pressure of an existing system by at least 50%.

DEFINITION OF BASELINE EQUIPMENT

The baseline for this measure is the existing irrigation system.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 5 years.⁶⁶

DEEMED MEASURE COST

As a retrofit measure, the actual installation and equipment costs are used.

Loadshape NRE11 – Nonresidential Agriculture

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = 0.746 * hours * \frac{Pressure * \frac{Flow}{Acre} * Acres}{1715 * Pump_{eff}}$$

Where:

Hours = hours irrigation system runs per season
 = 864 hr/yr⁶⁷

Pressure = reduction in pump pressure resulting from retrofit
 = Actual (PSI)

Acres = Actual

Flow per Acre = 5 gallons/minute/acre⁶⁸

⁶⁶ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014 (http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx)

⁶⁷ KEMA, Appendix F Program Evaluations Group 1 Vol 2; page 353

⁶⁸ KEMA, Appendix F Program Evaluations Group 1 Vol 2; page 353.

1715 = Conversion factor from PSI x GPM ((lb x gallons) / (sq. in x min)) to horsepower

Pump_{eff} = Actual, if unknown use 0.70⁶⁹

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

FLH = Full Load Hours
= 6768⁷⁰

CF = Summer System Peak Coincidence Factor 79.3%⁷¹

NATURAL GAS ENERGY 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: NR-AGE-LIRR-V03-240101

SUNSET DATE: 1/1/2027

⁶⁹ Appendix F Program Evaluations Group 1 Vol 2; page 354

⁷⁰ Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls

⁷¹ IA_Electric_Loadshapes.xls

3.1.13. Variable Speed Frequency Drive for Dairy Vacuum Pump and Milking Machine

DESCRIPTION

This measure characterizes the energy savings from the installation of VFDs on dairy vacuum pumps or replacement of existing constant speed dairy vacuum pumps with dairy vacuum pumps with variable speed capabilities.

A milk vacuum pump operates during the milk harvest and equipment washing periods. The vacuum pump creates negative air pressure that extracts milk from the cow and transfers it to either a milk receiver jar or to the milk cooling system bulk tank for storage. A VFD equipped on a milk vacuum pump allows the pump to reduce speed in order to adjust and deliver only the amount of vacuum needed.

This measure applies to the following markets: RF.

DEFINITION OF EFFICIENT EQUIPMENT

The criterion for this measure is the installation of a VFD on the milking vacuum pump. This measure applies only for blower-style pumps (not rotary-vane vacuum pumps).

DEFINITION OF BASELINE EQUIPMENT

The baseline is an existing pump without a VFD.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for a VFD is 15 years.⁷²

DEEMED MEASURE COST

Actual material and labor costs should be used. If actual costs are not known, as a default, the average equipment cost of a milk vacuum pump variable speed drive is \$3,871 with an installation cost of \$1,177, for a total default incremental measure cost of \$5,048.⁷³

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{((Hp - (0.25 * Milking Unit)) * 0.746 * LF)}{\eta_{motor}} * hours_{milk} * days_{milk}$$

Where:

Hp = Motor horsepower of the pump

⁷² 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014

(http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx)

⁷³ The default equipment and labor costs are source from the PG&E Workpaper – Milk Vacuum Pump VSD, Dairy Farm Equipment (PGE3PAGR116), February 2013.

Iowa Energy Efficiency Statewide Technical Reference Manual—3.1.13 Variable Speed Frequency Drive for Dairy Vacuum Pump and Milking Machine

	= Actual, if unknown, default to 10 hp ⁷⁴
0.25	= Constant. The amount of horsepower required per milking unit ⁷⁵ = 0.25 hp/milking unit
Milking Unit	= Number of milking units controlled by the vacuum pump = Actual, if unknown, default to 15.8 ⁷⁶
0.746	= Constant. Conversion factor from hp to kW = 0.746 kW/hp
LF	= Motor load factor = 90%
η_{motor}	= Motor efficiency = Actual, if unknown, default to 89.5% ⁷⁷
hours _{milk}	= Daily run hours of vacuum pump during milking = Actual, if unknown, default to 7.4 hours ⁷⁸
days _{milk}	= Milking days per year = 365.25 days

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLH = Full Load Hours

⁷⁴ The average vacuum pump motor horsepower is sourced from; “Energy Efficiency for Dairy Enterprises”, Sanford, Scott (University of Wisconsin-Madison), Presentation to Agricultural Life Sciences Program staff, December 2014. This value is further substantiated by the “Wisconsin Focus on Energy 2021 Technical Reference Manual”, Public Service Commission of Wisconsin, Cadmus.

⁷⁵ The amount of horsepower required per milking unit is sourced from the PG&E Workpaper – Milk Vacuum Pump VSD, Dairy Farm Equipment (PGE3PAGR116), February 2013

⁷⁶ The default number of milking units is sourced as an average of participating sites for the Wisconsin Focus on Energy program from January 2013 through May 2015. This value is further substantiated by the “Wisconsin Focus on Energy 2021 Technical Reference Manual”, Public Service Commission of Wisconsin, Cadmus.

⁷⁷ The motor efficiency is based on motor horsepower and NEMA energy efficient full load motor ratings. The default value is sourced as an average of participating sites for the Wisconsin Focus on Energy program from January 2013 through May 2015. This value is further substantiated by the “Wisconsin Focus on Energy 2021 Technical Reference Manual”, Public Service Commission of Wisconsin, Cadmus.

⁷⁸ The default daily run time of the vacuum pump during milking is based on an average run time of 3.7 hours per milking and 2 milkings per day. The average run time per milking is sourced from “Milking System Air Consumption When Using a Variable Speed Vacuum Pump”, Paper Number: 033014 - ASAE Meeting Presentation, July 2003. This value is further substantiated by the “Wisconsin Focus on Energy 2021 Technical Reference Manual”, Public Service Commission of Wisconsin, Cadmus. The number of milkings per day is consistent through other dairy measures in this TRM and is sourced from: Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List; Agricultural: Variable Frequency Drives-Dairy, FY2012, v1.2. Pre- and post-power meter data for five sites were used to establish RTF energy savings and the raw data used to generate load profiles showed, on average, two milkings per day. For further detail on the corroboration of this source, please see the 2016 Pennsylvania TRM.

Iowa Energy Efficiency Statewide Technical Reference Manual—3.1.13 Variable Speed Frequency Drive for Dairy Vacuum Pump and Milking Machine

CF = 2,703⁷⁹
= coincidence factor
= 79.3%⁸⁰

NATURAL GAS ENERGY 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: NR-AGE-VDVP-V05-230101

SUNSET DATE: 1/1/2028

⁷⁹ The annual full load hours equal the vacuum pump run time during milking multiplied by the number of milkings per day multiplied by the number of milking days per year [(2,703 hours) = (3.7 hours per milking) x (2 milkings per day) x (365.25 milking days per year)]

⁸⁰ Cadmus Loadshape analysis IA_Loadshapes.xls

3.1.14. Dairy Plate Cooler

DESCRIPTION

This measure characterizes the energy savings from the installation of plate-style milk precoolers on dairy parlor milk refrigeration systems. A plate cooler uses incoming well water to pre cool the milk before it enters the bulk tank reducing the cooling load on the compressors.

DEFINITION OF EFFICIENT EQUIPMENT

The criterion for this measure is the installation of a plate-style milk pre cooler in a dairy parlor; no additional efficiency qualifications.

DEFINITION OF BASELINE EQUIPMENT

The baseline is dairy parlor milk refrigeration systems, without existing plate-style milk pre cooler.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a plate cooler is 15 years.⁸¹

DEEMED MEASURE COST

Actual material and labor costs should be used.

If the actual installed cost is unknown, the default equipment cost of a plate cooler is \$2,950 with an installation cost of \$494, for a total incremental installed cost of \$3,444.⁸²

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kWh/Cow * NCows$$

Where:

kWh/Cow = Per cow annual energy savings from plate-style milk pre cooler in kWh/cow/yr.⁸³

Equipment Type	kWh/cow/year
Installed alone	76.2
Heat reclaimer installed with electric hot water heater	62.0
Scroll compressor installed	52.9
Both heat reclaimer (with electric hot water heater) and	65.0

⁸¹ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014

⁸² The equipment and labor costs are sourced from the PG&E Workpaper – Milk Pre Cooler (PGE3PAGR114), February 2013.

⁸³ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

Equipment Type	kWh/cow/year
scroll compressor installed	
Default if type not know ⁸⁴	66.5

NCows = Number of milking cows per farm
 = Actual, if unknown use 140⁸⁵

Savings Analysis:

$$\frac{\Delta kWh}{Cow} = (Days * C_{P,Milk} * Lbs\ of\ Milk * \Delta T - Btuh\ of\ Heat\ Recovery) * \frac{1}{EER} * \frac{1}{1000}$$

Where:

Days = Number of milking days per year
 = 365 days⁸⁶

C_{P,Milk} = Specific heat of milk⁸⁷
 = 0.93 Btu/(lb-°F)

Lbs of Milk = The pounds of milk produced per day per cow that needs to be cooled
 = 51.6 lbs of milk per cow per day⁸⁸

ΔT = Temperature reduction of the milk across precooler
 = 40°F⁸⁹

Btuh of Heat Recovery = Difference in Btu/h per cow per year recovered by heat reclaimer system with and without precooler
 = 0 Btu/h per cow per year if non-electric water heater
 = 131,562 Btu/h per cow per year if electric water heater and a heat reclaimer are present on-site⁹⁰

1000 = Conversion factor from watts to kilowatts⁹¹

EER = Energy Efficiency Ratio; efficiency of the existing compressor on the milk refrigeration system

⁸⁴ Default type if unknown is a weighted average assuming market penetration of 40% installed alone, 20% heat reclaimer installed, 20% scroll compressor installed and 20% heat reclaimer and scroll compressor installed. Source: Proportion based on IPL 2014 EEP assumptions the average of the four installation types.

⁸⁵ Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397. Average number of cows per farm = 223,579 cows / 1,592 farms = 140

⁸⁶ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

⁸⁷ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

⁸⁸ The pounds of milk produced per cow per day is based on an average cow producing 6 gallons of milk per day, with each gallon of milk weighting approximately 8.6 pounds (6 gallons of milk per cow per day x 8.6 lbs = 51.6 lbs of milk per cow per day). The milk production and density values are sourced from; IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 349 and 351.

⁸⁹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

⁹⁰ This factor acts as a negative interactive effect on the hot water heater only if a heat reclaimer is installed or in effect on site. This value is sourced from the 'Heat Reclaimer' measure and represents the difference in reclaimable heat between the hot water needs for the dairy farm and the waste heat available if a plate cooler is installed.

⁹¹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

= if installed with reciprocating compressor, use EER of 8.4⁹²

= if installed with unknown compressor type, use EER of 9.3⁹³

= if installed with scroll compressor, use EER of 10.9⁹⁴

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are based on the run time of compressors for medium temperature refrigeration applications.⁹⁵

= 3,910

CF = Coincidence factor

= 79%⁹⁶

NATURAL GAS ENERGY 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: NR-AGE-DYPC- V05-210101

SUNSET DATE: 1/1/2026

⁹² Average efficiency of a reciprocating compressor, as sourced from Wisconsin Focus on Energy TRM – Plate Heat Exchanger and Well Water Pre-Cooler, 2017

⁹³ Typical milk pre-cooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The baseline EER of 9.3 is from the Scroll Refrigerant Compressor measure baseline for 2HP compressor.

⁹⁴ Typical milk pre-cooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The scroll compressor EER of 10.9 is from the Scroll Refrigerant Compressor measure efficient option for 2HP compressor.

⁹⁵ Based on run time estimates from “Performance Standards for Walk-In Refrigerator and Freezer Systems,” AHRTI Report No. 09002-01, by Bryan R. Becker, et al., January 2012, Tables 30-33

⁹⁶ Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls

3.1.15. LED Grow Lights

DESCRIPTION

This measure is for the installation of LED grow lights for commercial agricultural purposes in interior or conditioned spaces. The assumption is the installed LEDs will be used for horticultural applications.

LEDs are a fast-emerging option for cultivating plants, and represent a significant efficiency increase over traditional high intensity discharge (HID) or linear fluorescent grow lights. Different from LEDs designed for visual applications and illuminating spaces for the human eye, grow lights efficacy are measured by their photosynthetic photon flux density (PPFD), instead of lumens. LEDs also offer interactive cooling savings due to the reduction in waste heat from an HID fixture, which typically requires an additional cooling source to maintain design cultivation temperatures and plant health.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is an LED grow light meeting the following criteria:

- Third-party tested and UL listed
- Power factor (PF) ≥ 0.90
- Photosynthetic photon efficacy (PPE) of no less than 2.3 micromoles per joule
- Minimum rated lifetime of 50,000 hours and a minimum warranty of 5 years for fixtures and 3 years for lamps
- LED fixture must be on the Design Lights Consortium qualifying products list⁹⁷

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the industry established grow light based on the horticultural application, as detailed in the table below. HID fixtures are assumed for flowering and vegetative crops. T5 high-output fixtures are assumed for seedling and microgreen crops.

Crop Type	Baseline Technology Type	Baseline PPE ($\mu\text{mol/J}$) ⁹⁸	Baseline Watts per Square Foot ⁹⁹	Baseline Fixture Wattage ¹⁰⁰
Flowering Crops (Tomatoes and Peppers)	High Pressure Sodium	1.7	52.5	840 W
Vegetative Growth	Metal Halide	1.25 ¹⁰¹	40	640 W

⁹⁷ Design Light Consortium – Horticultural Lighting, Testing and Reporting Requirements of LED-Based Horticultural Lighting, version 3.0, effective March 31, 2023

⁹⁸ Erik Runkle and Bruce Bugbee “Plant Lighting Efficiency and Efficacy: μmol per joule”. Accessed 4/21/2020.

⁹⁹ Jesse Remillard and Nick Collins, “Trends and Observations of Energy Use in the Cannabis Industry,” ACEEE, accessed April 17, 2020. Baseline watts per square foot were taken by using typical fixture technology by crop type and dividing by 16 sqft per fixture (a 4’x4’ area is a typical coverage amount for one grow light fixture).

¹⁰⁰ Jesse Remillard and Nick Collins, “Trends and Observations of Energy Use in the Cannabis Industry,” ACEEE, accessed April 17, 2020. Baseline watts per square foot were taken by using typical fixture technology by crop type and dividing by 16 sqft per fixture (a 4’x4’ area is a typical coverage amount for one grow light fixture).

¹⁰¹ Jacob A. Nelson, Bruce Bugbee, “Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures.” Utah State University. Accessed 5/6/2020.

Crop Type	Baseline Technology Type	Baseline PPE ($\mu\text{mol}/\text{J}$) ⁹⁸	Baseline Watts per Square Foot ⁹⁹	Baseline Fixture Wattage ¹⁰⁰
Microgreens ¹⁰²	T5 HO Fixture	0.84 ¹⁰³	22.5	360 W
Propagation ¹⁰⁴	T5 HO Fixture	0.84 ¹⁰⁵	15	240 W
Cannabis – Flowering Stage	High Pressure Sodium	1.7	68.8	1,100 W

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 9.5 years.¹⁰⁶

DEEMED MEASURE COST

For retrofit replacement scenarios, use actual installation costs. For time of sale installations, use the following incremental cost:

$$\text{Incremental cost}^{107} = (\$1.42 * \text{Watts}_{\text{LED}}) - \$65$$

Where:

\$1.42 = LED fixture wattage to incremental cost conversion factor

\$65 = LED fixture wattage to incremental cost offset

Watts_{LED} = LED fixture wattage

LOADSHAPE

Loadshape NRE11 - Nonresidential Agricultural

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (\text{Watts}_{\text{Base}} - (\text{Watts}_{\text{EE}} * \% \text{Dimming})) * \text{Area} * \text{Hours} * \text{WHF}_e / 1000 + \Delta kWh_{\text{Heating Penalty}}$$

Where:

ΔkWh = gross customer annual kWh savings

¹⁰² Microgreens T5 fixture is based on a 6-lamp high output fixture, based on program experience.

¹⁰³ Jacob A. Nelson, Bruce Bugbee, “Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures.” Utah State University. Accessed 5/6/2020.

¹⁰⁴ Propagation T5 fixture is based on a 4-lamp high output fixture, based on program experience.

¹⁰⁵ Jacob A. Nelson, Bruce Bugbee, “Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures.” Utah State University. Accessed 5/6/2020.

¹⁰⁶ The measure life is based on a minimum rated lifetime of 50,000 hours for DLC certified fixtures, divided by the average annual operating hours of 5,250 hours.

¹⁰⁷ The incremental cost is sourced from a linear regression analysis for LED fixture costs sourced from; “Trends and Observations of Energy Use in Cannabis Industry, ACEEE, 2017”. The LED equipment cost was supplemented by market research on baseline costs, the analysis of which can be seen: “IA TRM_LED Grow Lights_Cost_Apr 2020.xlsx”

Area = Illuminated plant canopy, in square feet, of active and growing space. Excludes all room area not associated with physical plants, such as room floor or aisles.

= Use actual if known. If unknown, default is 16 square feet per fixture¹⁰⁸

Hours = Annual hours of operation

= Use actual if known. If unknown, default by crop type:

Crop Types	Annual Hours ¹⁰⁹
Flowering Crops	4,200
Vegetative/Propagation Crops	6,300
Microgreens	6,300
Cannabis – Flowering Stage	4,200
Other	3,650
Average	5,250

1000 = Conversion from watts to kilowatts (W / kW)

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting.

HVAC Cooling Type	WHF _e ¹¹⁰
Cooling	1.21
No Cooling	1.00

Watts_{Base} = Baseline wattage per square foot of coverage/canopy area. See typical baseline wattages by crop type in baseline equipment definition.

Watts_{EE} = Efficient wattage per square foot of coverage/canopy area

= Actual. If crop type is unknown, default value is 36 watts per square foot¹¹¹

%Dimming = Average seasonal light intensity of the installed lights

= Actual. If unknown, default to 100%.

HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{Heating Penalty} = (Watts_{Base} - (Watts_{EE} * \%Dimming)) * Area * Hours * (-IFkWh) / 1000$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting.

¹⁰⁸ Default illuminated area is based on an average canopy grow area of 4 ft. x 4 ft.

¹⁰⁹ Sole-Source Lighting of Plants. Technically Speaking by Erik Runkle. Michigan State University Extension. September 2017. Accessed: 7/29/2019. Annual hours of operation were found by multiplying hours per day by 350 operating days per year. Assuming 5 crop cycles with 3 days of downtime between each cycle

¹¹⁰ Waste heat factor for cooling savings calculation is sourced from a custom analysis conducted by the 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 10.0, Volume 2: Commercial and Industrial Measures, Effective January 1, 2022 (4.1.11 Commercial LED Grow Lights).

¹¹¹ "Cannabis Energy Guidance", Massachusetts Department of Energy Resources, February 2019

HVAC Heating Type	IFkWh ¹¹²
Gas Heating	0.00
Electric Resistance Heating	0.284
Electric Heat Pump Heating	0.124

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (Watts_{Base} - (Watts_{EE} * \%Dimming)) * Area * CF * WHF_d / 1000$$

Where:

CF = 100%

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings.

HVAC Cooling Type	WHF _d ¹¹³
Cooling	1.22
No Cooling	1.00

NATURAL GAS SAVINGS

$$\Delta Therms = (Watts_{Base} - (Watts_{EE} * \%Dimming)) * Area * Hours * (-IFTherms) / 1000$$

Where:

ΔTherms = gross customer annual therms savings

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Value is based on the Non-Residential Average building type as selected from the Lighting Reference Table in Section 3.4, and detailed in the table below.

HVAC Heating Type	IFTherms ¹¹⁴
Gas Heating	0.01
Other Heating Type	0.00

PEAK GAS SAVINGS

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

Where:

¹¹² Waste heat factor for interative electric heating impacts is sourced from a custom analysis conducted by the 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 10.0, Volume 2: Commercial and Industrial Measures, Effective January 1, 2022 (4.1.11 Commercial LED Grow Lights).

¹¹³ Waste heat demand factor for cooling savings calculation is sourced from a custom analysis conducted by the 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 10.0, Volume 2: Commercial and Industrial Measures, Effective January 1, 2022 (4.1.11 Commercial LED Grow Lights).

¹¹⁴ Waste heat factor for thermal heating savings calculation is sourced from a custom analysis conducted by the 2022 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 10.0, Volume 2: Commercial and Industrial Measures, Effective January 1, 2022 (4.1.11 Commercial LED Grow Lights).

ΔTherms = Therm impact calculated above
 HeatDays = Heat season days per year
 = 190¹¹⁵

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Any costs associated with moving the LED lighting fixture to different heights throughout the different growing phases should also be included as an O&M consideration. See table below for default replacement assumptions:¹¹⁶

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
LED Grow Lights	Replacement of 150W High Pressure Sodium	50,000	\$207.65	70,000	\$40.00	24,000	\$29.00	40,000	\$47.00
	Replacement of 250W High Pressure Sodium	50,000	\$331.07	70,000	\$40.00	24,000	\$29.00	40,000	\$47.00
	Replacement of 400W High Pressure Sodium	50,000	\$533.64	70,000	\$62.50	24,000	\$31.00	40,000	\$205.00
	Replacement of 600W High Pressure Sodium	50,000	\$875.42	70,000	\$62.50	24,000	\$47.00	40,000	\$229.00
	Replacement of 1,000W High Pressure Sodium	50,000	\$1,557.58	70,000	\$62.50	24,000	\$80.00	40,000	\$255.00
	Replacement of 2 lamp-4 foot T5HO linear fluorescent lamp	50,000	\$207.65	70,000	\$40.00	30,000	\$26.33	40,000	\$60.00
	Replacement of 3 lamp-4 foot T5HO linear fluorescent lamp	50,000	\$207.65	70,000	\$40.00	30,000	\$39.50	40,000	\$60.00
	Replacement of 4 lamp-4 foot T5HO linear fluorescent lamp	50,000	\$331.07	70,000	\$40.00	30,000	\$52.67	40,000	\$75.00

MEASURE CODE: NR-AGE-GROW-V03-240101

SUNSET DATE: 1/1/2026

¹¹⁵ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

¹¹⁶ The baseline for this measure is assumed to be an HPS lamp or T5HO linear fluorescent lamp, depending on application, and are the established grow light for horticultural applications. The efficient equipment and the subsequent replacement costs are an equivalent LED grow light that is considered a suitable replacement based on industry research and manufacturer specifications.

3.1.16 Grain Bin Fan Aeration Controls

DESCRIPTION

A large portion of the corn produced every year has to be dried and stored in order to preserve for use in the future. When wet grain comes in from the field, it goes through a grain dryer to remove moisture and to prepare the grain for storage. Without the removal of moisture, stored grain can spoil or become moldy. For example, corn is typically stored with a moisture content of 15% or below. During the drying process, the corn is heated up and often goes into storage at temperatures at or above outdoor air temperatures.

Grain storage bins come in a variety of shapes and sizes. Some have capacities of a few thousand bushels and some have capacities of hundreds of thousands of bushels. When grain is stored in these large bins, the grain on the outer edges acts as an insulator for the grain in the middle. Because of this, as the outdoor air temperature drops, the grain, and surrounding air on the outside of the bin, cools down while the interior grain and air stays warm. As the warm air rises and the cool air sinks, convection currents of moving air transfer moisture to pockets within the grain. These pockets of moisture cause the grain to start rotting, which leads to spoilage, insect infestations, or other issues.

To prevent these moisture issues, grain storage bins are equipped with aeration fans that force air through the grain to keep the temperature gradients minimal and prevent convection currents from forming. Depending on the size (and especially height) of the bin, the fans often have significant horsepower to meet the CFM and static pressure requirements. Larger bins can easily require fan systems with four to six, 40-60hp fans, or larger.

Most grain bin aeration systems are manually controlled and there is quite a bit of guesswork involved with when to run the fans and for how long. The operation can be based on random grain samples, weather, or the operator's general judgement. Most of the time, this leads to erring on the side of caution and running the fans more than necessary. With the large fan motor horsepower involved, this leads to a lot of wasted energy.

Grain bin aeration fan controls use integrated moisture and temperature sensors embedded in the grain bin along with weather data to sense where and when issues may be occurring within the grain, and when the best times to dry the grain are. This removes a lot of the guesswork from the aeration fan system operation and results in a significant reduction in the hours of operation.

Savings are achieved by replacing existing manual controls on grain storage bin aeration fans with controls that use temperature and moisture sensors to modulate fan operation automatically. Electric savings are achieved in retrofit projects by reducing the aeration fan run hours. With manual controls, the fans are run more frequently and for longer than needed. The controls include moisture and temperature sensors which run the fans only when needed.

Grain bins using heating grain drying are not eligible for participation in this measure. The reported height of the grain bin must be the eave height and not the height of the peak. Bins larger than 105 ft. in diameter or 100 ft. in eave height must go through the custom program.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is grain bin aeration fans with automatic controls based on integrated temperature and/or moisture sensors.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is grain bin aeration fans with manual controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 7 years.¹¹⁷

DEEMED MEASURE COST

The actual installation cost should be used for screening and reporting purposes.

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Table: Default Annual kWh Savings Based on Bin Size

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
18	430	430	430	430	430	430	430	860	860	860	1,290	1,720
20	430	430	430	430	430	430	860	860	860	1,290	1,290	2,150
30	430	430	430	860	860	1,290	1,720	2,150	2,150	2,580	3,440	4,730
35	430	430	860	1,290	1,290	1,720	2,150	3,440	3,440	3,870	5,160	7,310
40	430	430	1,290	1,720	2,150	3,010	3,440	5,160	5,590	6,020	7,740	10,750
45	430	860	1,720	2,580	3,440	4,300	5,160	7,310	8,170	8,600	11,610	15,910
50	860	1,290	2,580	3,440	4,730	6,020	7,310	10,320	11,180	12,470	16,340	22,360
55	1,290	1,720	3,440	4,730	6,450	8,170	9,890	14,190	15,480	16,770	22,360	30,530
60	1,290	2,150	4,730	6,450	8,600	10,750	13,330	19,350	20,640	22,360	30,100	40,850
65	1,720	2,580	6,450	8,600	11,180	14,190	17,200	24,940	27,090	29,240	39,130	53,320
70	2,580	3,440	8,170	10,750	14,190	18,060	22,360	32,250	34,830	37,840	50,310	68,370
75	3,010	4,300	9,890	13,760	18,060	22,790	27,950	40,420	43,860	47,300	63,210	86,000
80	3,870	5,590	12,470	17,200	22,360	27,950	34,830	49,880	54,180	58,910	78,260	106,210
85	4,730	6,880	15,480	20,640	27,090	34,400	42,570	61,060	66,220	71,810	95,460	129,860
90	5,590	8,170	18,490	24,940	32,680	41,710	51,170	73,960	79,980	86,860	115,240	156,950
95	6,880	9,890	21,930	30,100	39,130	49,450	61,060	88,150	95,890	103,630	138,030	187,480
100	8,170	11,610	26,230	35,690	46,440	58,910	72,670	104,490	113,090	122,550	162,970	221,880

¹¹⁷ The expected measure life is based on bin dryer and their associated components (fans and heaters, stirring devices, continuous unloaders, etc.) as sourced from Purdue Extension, “Dryeration and Bin Cooling Systems for Grain”.

$$\Delta kWh = Fan_{BHP} * kWh \text{ Savings per Hp}$$

Where:

ΔkWh = gross customer annual kWh savings

$$kWh \text{ Savings per Hp} = \frac{0.746 * (Hours_{Manual} - Hours_{Control})}{Eff_{Motor}}$$

Where:

kWh Savings per Hp = The kWh savings per brake horsepower for grain bin aeration fans

= Default value is 430 kWh/hp

0.746 = Conversion factor from hp to kW

Hours_{Manual} = Annual hours of operation for grain storage bin aeration fans with manual controls

= 720 hours¹¹⁸

Hours_{Control} = Annual hours of operation for grain storage bin aeration fans with controls

= 180 hours¹¹⁹

Eff_{Motor} = Efficiency of the fan motor

= 93.6%¹²⁰

$$Fan_{BHP} = \frac{Design \text{ CFM} * Static \text{ Pressure}}{6356 * Eff_{Fan}} * (1 + Exhaust \text{ Fan Factor})$$

Where:

Fan_{BHP} = Fan brake horsepower (including motor loading) required to provide the necessary aeration to grain bin

= See table below for Fan BHP by Bin Size for default values¹²¹

6356 = Conversion factor from CFM-(in. wg) to horsepower

Eff_{Fan} = Efficiency of the fan

= 60%¹²²

Exhaust Fan Factor = Percentage of the aeration fan horsepower that can be attributed to the bin exhaust fans, which are also controlled in the system

= 5%¹²³

Static Pressure = The design static pressure of the stored grain required to be overcome by the aeration fan. Value as determined from the following polynomial where x is the bin eave height in

¹¹⁸ The default manual control hours are sourced from Alliant Energy Custom Rebate Project Data from 2013-2015

¹¹⁹ The default hours of operation of the fans with controls is sourced from Alliant Energy Custom Rebate Project Data from 2013-2015, leveraging Integris fan control runtime models.

¹²⁰ Motor efficiency is based on a NEMA Premium Efficient, 60 hp, ODP, 3600 RPM motor. This is a typical fan motor for larger bin sizes, as supported by Alliant Energy Custom Rebate Project Data from 2013-2015.

¹²¹ If the calculated fan brake horsepower resulted in a fractional value below 1, it was rounded up to 1 hp.

¹²² Typical rule of thumb for fans with high static pressure.

¹²³ The fan exhaust factor is sourced from Alliant Energy Custom Rebate Project Data from 2013-2015

feet, assuming the default value for CFM per Bushel of 0.17.¹²⁴

$$= ax^2 + bx + c$$

$$a = 0.002142472$$

$$b = -0.0679226$$

$$c = 1.212104147$$

Table: Default Static Pressure

Grain Depth (ft)	Static Pressure (in.wg)
	0.17 CFM per Bushel
18	0.68
20	0.71
30	1.10
40	1.92
50	3.17
60	4.85
70	6.96
80	9.49
90	12.45
100	15.84

$$Design\ CFM = Bushel\ Capacity * CFM\ per\ Bushel$$

Where:

Design CFM = The total CFM required per bushel for effective aeration

CFM per Bushel = CFM required per bushel for effective aeration

= 0.17 CFM per bushel¹²⁵

$$Bushel\ Capacity = \pi * \left(\frac{Diameter}{2}\right)^2 * Eave\ Height * Bushels\ per\ ft^3$$

Bushel Capacity = The total storage capacity of the grain storage bin, in bushels

= See table below for Bushel Capacity default values

Table: Bushel Capacity

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
18	4,547	6,547	14,731	20,050	26,188	33,144	40,919	58,923	63,935	69,152	92,067	125,313
20	5,052	7,274	16,367	22,278	29,098	36,827	45,465	65,470	71,039	76,836	102,297	139,237
30	7,578	10,912	24,551	33,417	43,647	55,240	68,198	98,205	106,559	115,254	153,445	208,855
35	8,840	12,730	28,643	38,986	50,921	64,447	79,564	114,572	124,319	134,463	179,019	243,665
40	10,103	14,549	32,735	44,556	58,195	73,654	90,930	130,940	142,079	153,672	204,593	278,474

¹²⁴ Kansas State University Research and Extension, "Aeration of Grain", April 2012

¹²⁵ Typical vendor design information, as supported by Alliant Energy Custom Rebate Project Data from 2013-2015.

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
45	11,366	16,367	36,827	50,125	65,470	82,860	102,297	147,307	159,838	172,881	230,167	313,283
50	12,629	18,186	40,919	55,695	72,744	92,067	113,663	163,674	177,598	192,090	255,741	348,092
55	13,892	20,005	45,010	61,264	80,019	101,274	125,029	180,042	195,358	211,299	281,315	382,902
60	15,155	21,823	49,102	66,834	87,293	110,480	136,395	196,409	213,118	230,508	306,890	417,711
65	16,418	23,642	53,194	72,403	94,567	119,687	147,762	212,777	230,878	249,717	332,464	452,520
70	17,681	25,460	57,286	77,973	101,842	128,894	159,128	229,144	248,637	268,926	358,038	487,329
75	18,944	27,279	61,378	83,542	109,116	138,100	170,494	245,512	266,397	288,135	383,612	522,139
80	20,207	29,098	65,470	89,112	116,391	147,307	181,861	261,879	284,157	307,344	409,186	556,948
85	21,470	30,916	69,562	94,681	123,665	156,514	193,227	278,247	301,917	326,553	434,760	591,757
90	22,733	32,735	73,654	100,251	130,940	165,720	204,593	294,614	319,677	345,762	460,334	626,566
95	23,995	34,553	77,745	105,820	138,214	174,927	215,959	310,981	337,437	364,971	485,909	661,376
100	25,258	36,372	81,837	111,390	145,488	184,134	227,326	327,349	355,196	384,180	511,483	696,185

Diameter = Diameter of the storage bin, in feet

Eave Height = Height of the storage bin walls before the roof begins, not to be confused with peak height, which is the top of the roof

Bushels per ft³ = Bushels per cubic foot (for storage)
 = If unknown, default is 0.804 Bu/ft³

Table: Fan BHP Based on Bin Size

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
18	1	1	1	1	1	1	1	2	2	2	3	4
20	1	1	1	1	1	1	2	2	2	3	3	5
30	1	1	1	2	2	3	4	5	5	6	8	11
35	1	1	2	3	3	4	5	8	8	9	12	17
40	1	1	3	4	5	7	8	12	13	14	18	25
45	1	2	4	6	8	10	12	17	19	20	27	37
50	2	3	6	8	11	14	17	24	26	29	38	52
55	3	4	8	11	15	19	23	33	36	39	52	71
60	3	5	11	15	20	25	31	45	48	52	70	95
65	4	6	15	20	26	33	40	58	63	68	91	124
70	6	8	19	25	33	42	52	75	81	88	117	159
75	7	10	23	32	42	53	65	94	102	110	147	200
80	9	13	29	40	52	65	81	116	126	137	182	247
85	11	16	36	48	63	80	99	142	154	167	222	302
90	13	19	43	58	76	97	119	172	186	202	268	365
95	16	23	51	70	91	115	142	205	223	241	321	436
100	19	27	61	83	108	137	169	243	263	285	379	516

Table: Design CFM

Bin Eave Height (ft)	Bin Diameter (ft)											
	20	24	36	42	48	54	60	72	75	78	90	105
18	773	1,113	2,504	3,409	4,452	5,634	6,956	10,017	10,869	11,756	15,651	21,303
20	859	1,237	2,782	3,787	4,947	6,261	7,729	11,130	12,077	13,062	17,390	23,670
30	1,288	1,855	4,174	5,681	7,420	9,391	11,594	16,695	18,115	19,593	26,086	35,505
35	1,503	2,164	4,869	6,628	8,657	10,956	13,526	19,477	21,134	22,859	30,433	41,423
40	1,718	2,473	5,565	7,574	9,893	12,521	15,458	22,260	24,153	26,124	34,781	47,341
45	1,932	2,782	6,261	8,521	11,130	14,086	17,390	25,042	27,173	29,390	39,128	53,258
50	2,147	3,092	6,956	9,468	12,367	15,651	19,323	27,825	30,192	32,655	43,476	59,176
55	2,362	3,401	7,652	10,415	13,603	17,217	21,255	30,607	33,211	35,921	47,824	65,093
60	2,576	3,710	8,347	11,362	14,840	18,782	23,187	33,390	36,230	39,186	52,171	71,011
65	2,791	4,019	9,043	12,309	16,076	20,347	25,119	36,172	39,249	42,452	56,519	76,928
70	3,006	4,328	9,739	13,255	17,313	21,912	27,052	38,955	42,268	45,717	60,866	82,846
75	3,220	4,637	10,434	14,202	18,550	23,477	28,984	41,737	45,288	48,983	65,214	88,764
80	3,435	4,947	11,130	15,149	19,786	25,042	30,916	44,519	48,307	52,249	69,562	94,681
85	3,650	5,256	11,825	16,096	21,023	26,607	32,849	47,302	51,326	55,514	73,909	100,599
90	3,865	5,565	12,521	17,043	22,260	28,172	34,781	50,084	54,345	58,780	78,257	106,516
95	4,079	5,874	13,217	17,989	23,496	29,738	36,713	52,867	57,364	62,045	82,604	112,434
100	4,294	6,183	13,912	18,936	24,733	31,303	38,645	55,649	60,383	65,311	86,952	118,351

SUMMER COINCIDENT PEAK DEMAND SAVINGS

There are no coincident peak demand savings associated with this measure.

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-GRAIN-V02-230101

SUNSET DATE: 1/1/2026

3.1.17. Dairy Refrigeration Tune-Up

DESCRIPTION

This tune-up is designed to assess all refrigeration equipment associated with a commercial-grade dairy farm facility with the intention of reducing electrical consumption.

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 refrigeration equipment associated with a commercial-grade dairy farm facility that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The certified technician must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks:

- Clean and inspect condenser and evaporator coils;
- Clean drain pan;
- Inspect/clean fans, screens, grills, filters, and drier cores;
- Inspect/adjust heat reclaim operation;
- Tighten all line voltage connections;
- Inspect/replace relays and capacitors as needed; and
- Add/remove refrigerant charge as needed.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is refrigeration equipment associated with a commercial-grade dairy farm facility that has not been inspected or tuned up in more than 12 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 3 years.¹²⁶

DEEMED MEASURE COST

Tune-up costs can vary considerably, particularly if refrigerant leak detection, remediation, and recharge is necessary. Actual invoiced tune-up costs should be used. If unknown, the default incremental cost is estimated to be \$194.¹²⁷

LOADSHAPE

Loadshape NRE01 - Non-Residential Refrigeration – Grocery

Algorithm

CALCULATION OF ENERGY SAVINGS

¹²⁶ The expected measure life is sourced from DEER2014 EUL Table for measures: “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”.

¹²⁷ Incremental cost is sourced from the 2020 Wisconsin Focus on Energy TRM, “Dairy Refrigeration Tune-Up”. The original source for the value is historical Wisconsin project data from 2018.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left((Days * C_{P,Milk} * Lbs\ of\ Milk * Cows * \Delta T) * \frac{1}{EER} * \frac{1}{1000} \right) * SF$$

Where:

Days	= Number of milking days per year = 365 days ¹²⁸
C _{P,Milk}	= Specific heat of milk ¹²⁹ = 0.93 Btu/(lb-°F)
Lbs of Milk	= The pounds of milk produced per day per cow that needs to be cooled = 51.6 lbs of milk per cow per day ¹³⁰
Cows	= Number of cows = Actual, if unknown use 140 cows ¹³¹
ΔT	= Temperature differential of milk this is mechanically cooled = 59°F if no pre-cooler is in operation = 29°F if a milk pre-cooler is in operation = 19°F if a milk pre-cooler is in operation with a milk transfer pump VFD
1000	= Conversion factor from watts to kilowatts ¹³²
EER	= Energy Efficiency Ratio; efficiency of the existing compressor on the milk refrigeration system (Btu/Wh) = if tune-up with reciprocating compressor, use EER of 8.4 ¹³³ = if tune-up with unknown compressor type, use EER of 9.3 ¹³⁴ = if tune-up with scroll compressor, use EER of 10.9 ¹³⁵
SF	= Energy savings factor = 5% ¹³⁶

¹²⁸ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

¹²⁹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

¹³⁰ The pounds of milk produced per cow per day is based on an average cow producing 6 gallons of milk per day, with each gallon of milk weighting approximately 8.6 pounds (6 gallons of milk per cow per day x 8.6 lbs = 51.6 lbs of milk per cow per day). The milk production and density values are sourced from; IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 349 and 351.

¹³¹ Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397. Average number of cows per farm = 223,579 cows / 1,592 farms = 140 cows/farm.

¹³² IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

¹³³ Average efficiency of a reciprocating compressor, as sourced from Wisconsin Focus on Energy TRM – Plate Heat Exchanger and Well Water Pre-Cooler, 2017

¹³⁴ Typical milk pre-cooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The baseline EER of 9.3 is from the Scroll Refrigerant Compressor measure baseline for 2HP compressor.

¹³⁵ Typical milk pre-cooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The scroll compressor EER of 10.9 is from the Scroll Refrigerant Compressor measure efficient option for 2HP compressor.

¹³⁶ Energy savings factor is sourced from the 2020 Wisconsin Focus on Energy TRM, “Dairy Refrigeration Tune-Up”. The original source for the value is an anecdotal conservative estimate from a University of Wisconsin-Madison extension associate.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

There are no associated coincident peak demand savings for this measure.

NATURAL GAS ENERGY 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: NR-AGE-TUNE-V01-220101

SUNSET DATE: 1/1/2026

3.1.18. ECM Ventilation Fan and Staging Controls

DESCRIPTION

ECM ventilation fans in agricultural applications offer significant savings opportunities over single-speed ventilation fans without staging controls. The combination of the intelligent controls with the ECM ventilation fans, allow for a multitude of control strategies that realize additional energy savings by reducing the speed of the fan motor. Although the complexity and intelligence of available controls can vary widely, this characterization claims savings strictly on ventilation fan staging based on temperature with additive fan speed reductions. Please note, savings for these controls require commissioning for optimal functionality, which may be unique to the site and design considerations.

These integrated controls typically operate through two signaling functions to the fan from the central controller. The first signal is an on/off indicator based on ambient temperature, very similar to the previous measure characterization, 'Temperature Based On/Off Ventilation Controller'. The controller is programmed to stage fan operation based on fan cooling needs as it relates to outdoor temperature. The second signal is a voltage variant that reduces the operating speed of the fan to better coordinate cooling needs with fan on/off staging. The efficient condition is an integrated fan controller strategy that claims additional savings from the reduced operating speed of ventilation fans.

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, a new ventilation controller is installed on new or existing ventilation fans. The fans must have ECM motors to fully realize the control savings.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a circuit of fans that do not have an integrated ventilation control strategy that can reduce the operating speed of the fans by varying the voltage. For fans that do not have an on/off temperature staging control in the baseline situation, it is assumed that fans are operated continuously in their maximum capacity from the first hot day in spring to last hot day in fall. For hog operations, "hot" is defined as temperatures above 60°F. For poultry operations, "hot" is defined as temperatures above 65°F. And for dairy operations, "hot" is defined as temperatures above 70°F. Additionally, it is assumed that for hog facilities, 30% of fans operate continuously, year-round to meet minimum ventilation requirements. For dairy facilities, 10% of fans are assumed to operate continuously. For baseline fans that do have an on/off temperature staging controller, the baseline run hours were reduced accordingly and in line with what is detailed in the 'Temperature Based On/Off Ventilation Controller' measure.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6.5 years.¹³⁷

DEEMED MEASURE COST

As a retrofit measure, the actual installation cost should be used for screening and reporting purposes.

LOADSHAPE

¹³⁷ Average motor life 35,000 hours as estimated by U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3. The measure life was then derived by dividing by the average ventilation fan run time by the default of unknown/other farm commodity, 5,305 hours.

Loadshape NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{base}}{1000} * hours_{Total} * Nfans - \sum \left(\frac{Nfans * Watts_{ee}}{1000} * \% Speed^{2.5} * Hours_{Speed} \right)$$

Where:

Watts_{base} = Connected load of baseline ventilation fans (watts).¹³⁸ If existing fans are not being replaced, and are ECM fans, use actual fan wattage.

Diameter of Fan (inches)	Watts_fan (0.05 SP)
14-23	382
24-35	550
36-47	879
48+	1353

hours_{Total} = Actual hours of operation. Typically, the fans will operate in a staged fashion such that only a fraction of total fans are operating in conditions that do not require maximum installed capacity. Accordingly, effective full load hours (EFLH) should be determined based on operating schedule and considering factors such as number of fans, stages, and temperature band definitions. If this information is unavailable, the table below may be used to reasonably estimate EFLH for hog, poultry, and dairy facilities, based on typical control schedules.¹³⁹

Existing Control Strategy	Facility Type	Annual EFLH
No Control Strategy	Hog	5,570
	Poultry	5,020
	Dairy	4,771
	Unknown/Other	5,305
Temperature	Hog	4,834

¹³⁸ University of Illinois, Department of Agriculture and Biological Engineering, Bioenvironmental and Structural Systems Laboratory (BESS Labs) – Agriculture Ventilation Fans, Performance, and Efficiencies database download, as accessed on 7/1/2015. Average watts from models below standard (minimum efficiency requirement detailed in the efficient equipment definition). For more detail, see: “AgVentilationFans.xls”

¹³⁹ See “Ag Op Hours_2023.xlsx” workbook for a complete description and derivation of default operating hours. EFLH based on NCDC US Climate Normals 15-yr Hourly data for Des Moines (2006-2020). The unknown/other commodity type is a weighted average of hog, poultry, and dairy facilities based on farm count as sourced from the U.S. 2017 Agriculture Census for Iowa. The temperature on/off staging control run hours represent the difference between the fan run time if no control strategy is in place and the reduction in fan run hours associated with an on/off temperature controller, as sourced from the ‘3.1.4 Temperature Based On/Off Ventilation Controller’ measure.

Existing Control Strategy	Facility Type	Annual EFLH
On/Off Staging Control	Poultry	4,369
	Dairy	4,713
	Unknown/Other	4,673

N_{fans} = Number of ventilation fans

= Actual

$Watts_{ee}$ = Connected load of efficient ECM ventilation fans (watts)

= Actual

$\% Speed$ = Speed reduction of efficient ECM ventilation fan due to staging controls and operating setting of controller, at specified temperature and operational bin

= Actual

$Hours_{Speed}$ = Efficient ECM ventilation fan run hours at specified reduced operating speed due to controller programming

= Actual

For example, a dairy stall barn replaced 30 existing, 42" diameter, single-speed, ventilation fans with 30, 42" diameter high efficiency ECM ventilation fans with integrated controls that can vary the speed of the fans. The efficient ECM ventilation fans have a rated wattage of 565 watts at full speed. The set control strategy, as programmed by the installer, is as follows:

Number of Fans	Temperature Bin	Annual Operating Hours	Fan Speed
30	≥ 70°F	2,099	100%
20	≥ 60°F and < 70°F	2,230	75%
15	≥ 55°F and < 60°F	1,115	75%
15	≥ 50°F and < 55°F	1,115	50%
8	< 50°F	2,202	100%

$$\Delta kWh = \frac{879}{1000} * 4205 * 30 - \sum \left(\frac{30 * 565}{1000} * 1^{2.5} * 2099 \right), \left(\frac{20 * 565}{1000} * 0.75^{2.5} * 2230 \right), \left(\frac{15 * 565}{1000} * 0.75^{2.5} * 1115 \right), \left(\frac{15 * 565}{1000} * 0.5^{2.5} * 1115 \right), \left(\frac{8 * 565}{1000} * 1^{2.5} * 2202 \right)$$

= 46,806 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A - Assume no change in fan operation during summer coincident peak period, as fans will be running regardless of thermostat controls and therefore no savings during peak period.

NATURAL GAS ENERGY 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: NR-AGE-ECMV-V03-240101

SUNSET DATE: 1/1/2028

3.1.19. Grain Dryer Tune-Up

DESCRIPTION

This tune-up is designed to assess a heated grain dryer with the intention of reducing electrical consumption. This measure can apply to all types of harvested grain; however, this measure characterization defaults savings to shelled corn, which is the most common dried and stored grain.

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 grain drying equipment associated with a commercial-grade farm facility that has been inspected, cleaned, and tuned. The certified technician must abide by all rules and regulations related to grain dryer testing and safety protocols and must conduct the following tasks:

- Clean and inspect screens;
- Clean and inspect fans;
- Clean and calibrate all temperature sensors;
- Clean and calibrate all moisture sensors, if applicable;
- Inspect and adjust grain dryer controls, including temperature setpoints for maximum efficacy;
- Lubricate bearings;
- Tighten all line voltage connections; and
- Inspect/replace relays and capacitors as needed; and

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is grain drying equipment associated with a commercial-grade farm facility that has not been inspected or tuned up in more than 12 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 1 years.¹⁴⁰

DEEMED MEASURE COST

Tune-up costs can vary considerably, particularly if refrigerant leak detection, remediation, and recharge is necessary. Actual invoiced tune-up costs should be used. If unknown, the default incremental cost is estimated to be \$317.¹⁴¹

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

¹⁴⁰ The expected measure life is sourced from “Low-Cost Energy Conservation: Grain Drying”, University of Wisconsin-Madison Extension, Scott Sanford (A3784-10), 2003.

¹⁴¹ Incremental cost is sourced from the 2022 Wisconsin Focus on Energy TRM, “Grain Dryer Tune-Up”. The original source for the value is historical Wisconsin project data from 2019, and represents a weighted average in tune-up costs between natural gas- and propane-fueled grain dryers.

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{\text{Acres} * \frac{\text{Bushels}}{\text{Acre}} * \text{Lbs}_{\text{Bushels}} * \text{Eff} * \text{MS}}{3,412} \right) * \% \text{Elec} * \text{SF}$$

Where:

- Acres = Number of acres planted that will be dried using the grain dryer
= Actual
- Bushels/Acre = Average number of bushels per acre of grain
= Actual. If unknown, default is 182.4 bushels per acre.¹⁴²
- Lbs_{Bushels} = Initial bushel weight determined from grain moisture content percentage and corresponding weight.
= Actual. If unknown, default is 61.37 lbs per bushel.¹⁴³
- 3,412 = Constant conversion factor from Btus to kW
- Eff = Existing grain dryer efficiency in Btus per pounds of water removed.
= See table below for assumed values as efficiency varies depending on type and functionality of heated grain dryer.

Grain Dryer Type	Grain Dryer Efficiency (Btus/Lbs _{H2O}) ¹⁴⁴
Continuous Cross Flow Dryer (included Tower Dryers)	2,800
Batch Cross Flow Dryer	2,450
High Temperature Batch Bin Dryer	2,430
Mixed Flow Dryer	2,050
Continuous Flow In-Bin Dryer	2,000

- %Elec = Percentage of total energy consumed that is electric
= 2%¹⁴⁵
- SF = Energy savings factor

¹⁴² The average bushels of acre assumes corn as the grain commodity and is sourced from the U.S. Department of Agriculture, National Agricultural Statistics Services Quick Stats Ad-hoc Query Tool, as accessed on April 7, 2022. Queried bushels per acre of corn yields, annually, for Iowa spanning from 2010 through 2021.

¹⁴³ Tables for Weights and Measurement – Crops, University of Missouri-Columbia, Department of Agronomy, William Murphy, October 1, 1993.

¹⁴⁴ Grain dryer efficiencies are approximate as they can vary slightly depending on grain commodity, harvested and initial moisture content, final moisture content, and system calibration. The assumed grain dryer efficiencies are sourced from; “Improving Energy Efficiency in Grain Drying: Continuous Flow Dryers (Fact Sheet)”, University of Wisconsin-Madison, Extension, December 2012. Additionally, “Energy Self-Assessment, Step 2: Informational Section”, U.S. Department of Agriculture – Grain Drying Energy Efficiency and Energy Cost Graph.

¹⁴⁵ “Energy Conservation and Alternative Sources for Corn Drying”, The National Corn Handbook, March 14, 2016 (NCH-14, page 3, Table 4)

= 5%¹⁴⁶

MS = Moisture shrink is the percent weight reduction of wet grain as it is dried in the grain dryer. Use equation below if initial and final moisture contents are known. If unknown, default is 9.51%.¹⁴⁷

$$MS = \frac{(MC_i - MC_f)}{(1 - MC_f)}$$

Where:

MC_i = Initial moisture content
 = Actual, if unknown, default is 22.9%¹⁴⁷

MC_f = Final moisture content
 = Actual, if unknown, default is 14.8%¹⁴⁷

SUMMER COINCIDENT PEAK DEMAND SAVINGS

There are no associated coincident peak demand savings for this measure.

NATURAL GAS ENERGY SAVINGS

$$\Delta Thrms = \left(\frac{Acres * \frac{Bushels}{Acre} * Lbs_{Bushels} * Eff * MS}{100,000} \right) * (1 - \%Elec) * SF$$

Where:

100,000 = Constant conversion factor from Btus to natural gas therms

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-GDTUNE-V01-230101

SUNSET DATE: 1/1/2026

¹⁴⁶ Energy savings factor is sourced from the 2022 Wisconsin Focus on Energy TRM, “Grain Dryer Tune-Up”. The original source for the value is an anecdotal conservative estimate from a grain dryer manufacturer sales director.

¹⁴⁷ Moisture contents and moisture removed through the grain drying process is sourced from the 2022 Wisconsin Focus on Energy TRM, “Grain Dryer Tune-Up”. The original source for the value is derived from actual project data for the program, spanning 2014 through 2020.

3.2. Hot Water

3.2.1. Low Flow Faucet Aerators

DESCRIPTION

This measure relates to the direct installation of a low flow faucet aerator in a commercial building. Expected applications include small business, office, restaurant, motel, and hotel. For multifamily or senior housing, the residential low flow faucet aerator characterization should be used.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an energy efficient faucet aerator, rated at 1.5 gallons per minute (GPM)¹⁴⁸ 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 GPM¹⁴⁹ or greater. Note: if flow rates are measured, for example through a Direct Install program, then actual baseline flow rates should be used rather than the deemed values.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 9 years.¹⁵⁰

DEEMED MEASURE COST

The incremental installed cost for this measure is \$16,¹⁵¹ or program actual cost.

LOADSHAPE

Loadshape NREW01:16 - Nonresidential Electric Hot Water (by Building Type)

Loadshape NRGW01:16 – Nonresidential Gas Hot Water (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are per faucet retrofitted.¹⁵²

¹⁴⁸ IPL program product data for 2014 Iowa Residential Energy Assessments.

¹⁴⁹ DOE Energy Cost Calculator for Faucets and Showerheads:

(http://www1.eere.energy.gov/femp/technologies/eep_faucets_showerheads_calc.html#output)

¹⁵⁰ Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. "http://neep.org/Assets/uploads/files/emv/emv-library/measure_life_GDS%5B1%5D.pdf"

¹⁵¹ 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)).

¹⁵² This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture. Due to the distribution of water consumption by fixture type, as well as the different number of fixtures in a building, several variables must be incorporated.

$$\Delta kWh = \%ElectricDHW * \frac{GPM_base - GPM_low}{GPM_base} * Usage * EPG_electric * ISR$$

Where:

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

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	53% ¹⁵³

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

= Measured full throttle flow * 0.83 throttling factor¹⁵⁴

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 factor¹⁵⁵

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

Usage = Estimated usage of mixed water (mixture of hot water from water heater line and cold water line) per faucet (gallons per year)

= If data is available to provide a reasonable custom estimate, it should be used - if not, use the following defaults (or substitute custom information in to the calculation):

Building Type	Gallons hot water per unit per day ¹⁵⁶ (A)	Unit	Estimated % total building hot water use from Faucets ¹⁵⁷ (B)	Multiplier ¹⁵⁸ (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
Small Office	1	person	100%	10	employees per faucet	250	2,500
Large Office	1	person	100%	45	employees per faucet	250	11,250
Fast Food Rest	0.7	meal/day	50%	75	meals per faucet	365.25	9.588
Sit-Down Rest	2.4	meal/day	50%	36	meals per faucet	365.25	15,779
Retail	2	employee	100%	5	employees per faucet	365.25	3,653
Grocery	2	employee	100%	5	employees per faucet	365.25	3,653

¹⁵³ Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region, see ‘CBECS_B32 Water heating energy sources, floorspace, 2012.xls’. If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used.

¹⁵⁴ 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

¹⁵⁵ 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

¹⁵⁶ Table 2-45 Chapter 49, Service Water Heating, 2007 ASHRAE Handbook, HVAC Applications.

¹⁵⁷ Estimated based on data provided in Appendix E; “Waste Not, Want Not: The Potential for Urban Water Conservation in California”; http://www.pacinst.org/reports/urban_usage/appendix_e.pdf

¹⁵⁸ Based on review of the plumbing code (Employees and students per faucet). Retail, grocery, warehouse, and health are estimates. Meals per faucet estimated as 4 bathroom and 3 kitchen faucets and average meals per day of 250 (based on California study above) – 250/7 = 36. Fast food assumption estimated.

Building Type	Gallons hot water per unit per day ¹⁵⁶ (A)	Unit	Estimated % total building hot water use from Faucets ¹⁵⁷ (B)	Multiplier ¹⁵⁸ (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
Warehouse	2	employee	100%	5	employees per faucet	250	2,500
Elementary School	0.6	person	50%	50	students per faucet	200	3,000
Jr High/High School	1.8	person	50%	50	students per faucet	200	9,000
Health	90	patient	25%	2	Patients per faucet	365.25	16,436
Motel	20	room	25%	1	faucet per room	365.25	1,826
Hotel	14	room	25%	1	faucet per room	365.25	1,278
Other	1	employee	100%	20	employees per faucet	250	5,000

$$\begin{aligned}
 \text{EPG_electric} &= \text{Energy per gallon of mixed water used by faucet (electric water heater)} \\
 &= (\gamma_{\text{Water}} * 1.0 * (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE_electric} * 3412) \\
 &= 0.0822 \text{ kWh/gal if resistance tank (or unknown)}^{159} \\
 &= 0.0403 \text{ kWh/gal if heat pump water heater}
 \end{aligned}$$

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
= 86F for Bath, 93F for Kitchen
- SupplyTemp = Assumed temperature of water entering building
= 56.5¹⁶⁰
- RE_electric = Recovery efficiency of electric water heater
= 98% for electric resistance (or unknown)¹⁶¹
= 200% for heat pump water heaters¹⁶²
- 3412 = Converts Btu to kWh (Btu/kWh)

¹⁵⁹ Assumes 50:50 kitchen and bathroom usage.

¹⁶⁰ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. <http://www.nrel.gov/docs/fy10osti/47246.pdf>; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

¹⁶¹ Electric water heaters have recovery efficiency of 98%: <https://www.ahridirectory.org/Search/SearchHome>

¹⁶² 200% 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 faucet aerators

=Assumed to be 1.0

Based on defaults provided above:¹⁶³

Building Type	ΔkWh		
	Resistance Tank	Heat Pump Tank	Unknown DHW
Small Office	44.9	22.0	23.8
Large Office	202.2	99.1	107.1
Fast Food Rest	172.3	84.4	91.3
Sit-Down Rest	283.5	138.8	150.3
Retail	65.6	32.1	34.8
Grocery	65.6	32.1	34.8
Warehouse	44.9	22.0	23.8
Elementary School	53.9	26.4	28.6
Jr High/High School	161.7	79.2	85.7
Health	295.3	144.6	156.5
Motel	32.8	16.1	17.4
Hotel	23.0	11.2	12.2
Other	89.8	44.0	47.6

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = calculated value above on a per faucet basis

Hours = Annual electric DHW recovery hours for faucet use

$$= (Usage * 0.479^{164}) / GPH$$

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 70F temp rise (126.5-56.5), 98% for resistance (or unknown) and 200% for heat pump water tanks recovery efficiency, and typical 12kW electric resistance storage tank.¹⁶⁵

= 68.8 if resistance tank, 140.4 if heat pump

= Calculate if usage is custom, if using default usage use:

Building Type	Annual Recovery Hours	
	Resistance Tank	Heat Pump Tank
Small Office	17.4	8.5
Large Office	78.3	38.4
Fast Food Rest	66.7	32.7
Sit-Down Rest	109.8	53.8
Retail	25.4	12.5
Grocery	25.4	12.5

¹⁶³ See “Commercial Faucet Aerator Calculations_06122019.xlsx” for details.

¹⁶⁴ 47.9% is the proportion of hot 126.5F water mixed with 56.5F supply water to give 90°F mixed faucet water.

¹⁶⁵ See “Calculation of GPH Recovery_06122019.xlsx” for more information.

Building Type	Annual Recovery Hours	
	Resistance Tank	Heat Pump Tank
Warehouse	17.4	8.5
Elementary School	20.9	10.2
Jr High/High School	62.7	30.7
Health	114.4	56.0
Motel	12.7	6.2
Hotel	8.9	4.4
Other	34.8	17.1

CF = Coincidence Factor for electric load reduction

= Dependent on building type¹⁶⁶

Building Type	Coincidence Factor	
	Resistance Tank	Heat Pump Tank
Small Office	0.45%	0.16%
Large Office	2.38%	0.83%
Fast Food Rest	1.14%	0.40%
Sit-Down Rest	2.50%	0.88%
Retail	0.58%	0.20%
Grocery	0.58%	0.20%
Warehouse	0.60%	0.21%
Elementary School	0.54%	0.19%
Jr High/High School	1.61%	0.56%
Health	1.96%	0.69%
Motel	0.09%	0.03%
Hotel	0.06%	0.02%
Other	1.19%	0.42%

Based on defaults provided above:¹⁶⁷

Building Type	ΔkW		
	Resistance Tank	Heat Pump Tank	Unknown DHW
Small Office	0.0115	0.0057	0.0061
Large Office	0.0615	0.0302	0.0326
Fast Food Rest	0.0295	0.0144	0.0156
Sit-Down Rest	0.0647	0.0317	0.0343
Retail	0.0150	0.0073	0.0079
Grocery	0.0150	0.0073	0.0079
Warehouse	0.0154	0.0075	0.0082
Elementary School	0.0138	0.0068	0.0073
Jr High/High School	0.0415	0.0204	0.0220
Health	0.0505	0.0248	0.0268
Motel	0.0022	0.0011	0.0012

¹⁶⁶ Calculated as follows: Assumptions for percentage of usage during peak period (2-6pm) were made and then multiplied by 65/365 (65 being the number of days in peak period) and by the number of total annual recovery hours to give an estimate of the number of hours of recovery during peak periods. There are 260 hours in the peak period, so the probability there will be savings during the peak period is calculated as the number of hours of recovery during peak divided by 260. See 'Commercial Faucet Aerator Calculations_06122019.xlsx' for details.

¹⁶⁷ See "Commercial Faucet Aerator Calculations_06122019.xlsx" for details.

Building Type	ΔkW		
	Resistance Tank	Heat Pump Tank	Unknown DHW
Hotel	0.0016	0.0008	0.0008
Other	0.0308	0.0151	0.0163

NATURAL GAS SAVINGS

$$\Delta Therms = \%FossilDHW * \frac{GPM_base - GPM_low}{GPM_base} * Usage * EPG_gas * ISR$$

Where:

%FossilDHW = proportion of water heating supplied by fossil fuel heating

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	47% ¹⁶⁸

EPG_gas = Energy per gallon of mixed water used by faucet (gas water heater)
 = (8.33 * 1.0 * (WaterTemp¹⁶⁹ - SupplyTemp)) / (RE_gas * 100,000)
 = 0.0035 Therm/gal for buildings with storage tank, 0.0047 Therm/gal if hot water through central boiler or 0.0040 Therm/gal if unknown

Where:

RE_gas = Recovery efficiency of gas water heater
 = 69%¹⁷⁰

= 78% for buildings with storage tank, 59% if hot water through central boiler, or 69% if unknown¹⁷¹

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

Other variables as defined above.

Based on defaults provided above:¹⁷²

Building Type	ΔTherms			
	Buildings with Storage tank	Buildings with Central Boiler DHW	Unknown Gas DHW	Unknown DHW
Small Office	1.9	2.5	2.2	1.0
Large Office	8.7	11.5	9.8	4.6
Fast Food Rest	7.4	9.8	8.3	3.9

¹⁶⁸ Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region, see 'CBECS_B32 Water heating energy sources, floorspace, 2012.xls'. If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used.

¹⁶⁹ Assumes 50:50 kitchen and bathroom usage.

¹⁷⁰ Commercial properties are often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .78 for single family home. An average is used for this analysis by default.

¹⁷¹ 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 water heating system is unknown.

¹⁷² See "Commercial Faucet Aerator Calculations_06122019.xlsx" for details.

Building Type	ΔTherms			
	Buildings with Storage tank	Buildings with Central Boiler DHW	Unknown Gas DHW	Unknown DHW
Sit-Down Rest	12.2	16.1	13.7	6.5
Retail	2.8	3.7	3.2	1.5
Grocery	2.8	3.7	3.2	1.5
Warehouse	1.9	2.5	2.2	1.0
Elementary School	2.3	3.1	2.6	1.2
Jr High/High School	6.9	9.2	7.8	3.7
Health	12.7	16.7	14.3	6.7
Motel	1.4	1.9	1.6	0.7
Hotel	1.0	1.3	1.1	0.5
Other	3.9	5.1	4.4	2.0

PEAK GAS SAVINGS

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

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

Where:

ΔTherms = Therm impact calculated above

365.25 = Days per year

Based on defaults provided above:¹⁷³

Building Type	ΔPeakTherms			
	Buildings with Storage tank	Buildings with Central Boiler DHW	Unknown Gas DHW	Unknown DHW
Small Office	0.0053	0.0070	0.0060	0.0028
Large Office	0.0237	0.0314	0.0268	0.0126
Fast Food Rest	0.0202	0.0267	0.0228	0.0107
Sit-Down Rest	0.0333	0.0440	0.0376	0.0177
Retail	0.0077	0.0102	0.0087	0.0041
Grocery	0.0077	0.0102	0.0087	0.0041
Warehouse	0.0053	0.0070	0.0060	0.0028
Elementary School	0.0063	0.0084	0.0072	0.0034
Jr High/High School	0.0190	0.0251	0.0215	0.0101
Health	0.0346	0.0458	0.0392	0.0184
Motel	0.0038	0.0051	0.0044	0.0020
Hotel	0.0027	0.0036	0.0030	0.0014
Other	0.0105	0.0139	0.0119	0.0056

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Gallons = \frac{GPM_{base} - GPM_{low}}{GPM_{base}} * Usage * ISR$$

¹⁷³ See “Commercial Faucet Aerator Calculations_06122019.xlsx” for details.

Variables as defined above

Based on defaults provided above:¹⁷⁴

Building Type	ΔGallons
Small Office	546
Large Office	2459
Fast Food Rest	2094
Sit-Down Rest	3447
Retail	798
Grocery	798
Warehouse	546
Elementary School	656
Jr High/High School	1967
Health	3590
Motel	399
Hotel	279
Other	1093

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HWE-LFFA-V04-220101

SUNSET DATE: 1/1/2026

¹⁷⁴ See “Commercial Faucet Aerator Calculations_06122019.xlsx” for details.

3.2.2. Low Flow Showerheads

DESCRIPTION

This measure relates to the direct installation of a low flow showerhead in a commercial building. Expected applications include small business, office, motel, and hotel. For multifamily or senior housing, the residential low flow showerhead should be used.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an energy efficient showerhead rated at 1.5 gallons per minute (GPM) or less. Savings are calculated on a per showerhead fixture basis.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a standard showerhead rated at 2.5 GPM.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.¹⁷⁵

DEEMED MEASURE COST

The incremental installed cost for this measure is \$20¹⁷⁶ or program actual.

LOADSHAPE

Loadshape NREW01:16 - Nonresidential Electric Hot Water (by Building Type)

Loadshape NRGW01:16 – Nonresidential Gas Hot Water (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture:

$$\Delta kWh = \%ElectricDHW * ((GPM_{base} - GPM_{low}) * L * SPD * Days) * EPG_{electric} * ISR$$

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%

¹⁷⁵ Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multifamily buildings.

¹⁷⁶ Direct-install price per showerhead assumes cost of showerhead (Market research average of \$7 and assess and install time of \$13 (20min @ \$40/hr).

DHW fuel	%ElectricDHW
Unknown	53% ¹⁷⁷

- GPM_base = Flow rate of the baseline showerhead
= Actual measured flow rate - If not measured, assume 2.5 GPM¹⁷⁸
- GPM_low = Flow rate of the low-flow showerhead
= Actual measured flow rate - If not measured, assume 1.5 GPM
- (L * SPD * Days) = Minutes of use per showerhead annually. Ideally, this should be calculated using the following inputs (if unknown defaults are provided below):
 - L = Shower length in minutes with showerhead
= 7.8 min¹⁷⁹
 - SPD = Showers Per Day for showerhead
= Input estimate (if unknown see table below)
 - Days = Days used per year, on average
= Actual (if unknown see table below)

If it is not possible to provide a reasonable custom estimate for annual showerhead minutes, the following defaults can be used:¹⁸⁰

Building Type	Annual Minutes per Showerhead (L * SPD * Days)
Hospitality	3,509
Health	2,528
Commercial – Employee Shower	1,894
Education	2,057
Other Commercial Except Fitness Center	3,029
Fitness Center	56,893

- EPG_electric = Energy per gallon of hot water supplied by electric
= $(\gamma_{Water} * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)$
= 0.1109 kWh/gal for resistance (or unknown) unit, 0.0543 kWh/gal for heat pump water heaters

¹⁷⁷ Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region, see 'CBECS_B32 Water heating energy sources, floorspace, 2012.xls'. If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used.

¹⁷⁸ The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

¹⁷⁹ Assumed consistent with Residential assumption; 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.

¹⁸⁰ Default values are based upon a Northwest Power and Conservation Council Regional Technical Forum workbook, see "ComDHWShowerhead_v3_0.xls". Estimates are derived based on a combination of evaluation assumptions, surveys and professional judgment.

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 = 101F ¹⁸¹
SupplyTemp	= Assumed temperature of water entering house = 56.5 ¹⁸²
RE_electric	= Average Recovery efficiency of electric water heater = 98% for electric resistance (or unknown) ¹⁸³ = 200% for heat pump water heaters ¹⁸⁴
3412	= Converts Btu to kWh (Btu/kWh)
ISR	= In service rate of showerhead = 1.0

For example, for a direct-installed 1.5 GPM showerhead in an office open every day with electric DHW where the number of showers is estimated at 3 per day:

$$\begin{aligned} \Delta kWh &= 1 * ((2.5 - 1.5) * 7.8 * 3 * 365.25) * 0.111 * 1.0 \\ &= 948.7 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh	= calculated value above
Hours	= Annual electric DHW recovery hours for showerhead use = (GPM_base * L * SPD * 365.25 * 0.65 ¹⁸⁵) / GPH

Where:

GPH	= Gallons per hour recovery of electric water heater calculated for 70F temp rise (126.5-
-----	---

¹⁸¹ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

¹⁸² Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. <http://www.nrel.gov/docs/fy10osti/47246.pdf>; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

¹⁸³ Electric water heaters have recovery efficiency of 98%: <https://www.ahridirectory.org/Search/SearchHome>

¹⁸⁴ 200% 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.

¹⁸⁵ 65.0% is the proportion of hot 125F water mixed with 56.5F supply water to give 101F shower water.

56.5), 98% recovery efficiency for electric resistance (or unknown) and 200% for heat pump water heaters, and typical 12kW electric resistance storage tank.¹⁸⁶

= 68.8 if resistance tank, 140.4 if heat pump

CF = Coincidence Factor for electric load reduction
= 1.6%¹⁸⁷

For example, for a direct-installed 1.5 GPM showerhead in an office with electric resistance DHW where the number of showers is estimated at 3 per day:

$$\begin{aligned} \Delta kW &= (948.7 / 202) * 0.016 \\ &= 0.075 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta Therms = \%FossilDHW * (GPM_{base} - GPM_{low}) * L * SPD * Days * EPG_{gas} * ISR$$

Where:

%FossilDHW = proportion of water heating supplied by fossil fuel heating

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	47% ¹⁸⁸

EPG_gas = Energy per gallon of Hot water supplied by gas
= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)
= 0.0048 Therm/gal for buildings with storage tank, 0.0063 Therm/gal if hot water through central boiler or 0.0054 Therm/gal if unknown

Where:

RE_gas = Recovery efficiency of gas water heater
= 78% for buildings with storage tank, 59% if hot water through central boiler or 69% if unknown¹⁸⁹
100,000 = Converts Btus to Therms (Btu/Therm)

Other variables as defined above.

¹⁸⁶ See "Calculation of GPH Recovery_06122019.xlsx" for more information.

¹⁸⁷ Assume consistent with residential assumption. 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.

¹⁸⁸ Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region, see 'CBECS_B32 Water heating energy sources, floorspace, 2012.xls'. If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used.

¹⁸⁹ 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.

For example, for a direct-installed 1.5 GPM showerhead in an office open every day with gas DHW (unknown system) where the number of showers is estimated at 3 per day:

$$\begin{aligned} \Delta\text{Therms} &= 1.0 * (2.5 - 1.5) * 7.8 * 3 * 365.25 * 0.0054 * 1.0 \\ &= 46.2 \text{ therms} \end{aligned}$$

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:

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

Where:

- ΔTherms = Therm impact calculated above
- 365.25 = Days per year

For example, for a direct-installed 1.5 GPM showerhead in an office open every day with gas DHW where the number of showers is estimated at 3 per day:

$$\begin{aligned} \Delta\text{PeakTherms} &= 46.2 / 365.25 \\ &= 0.1265 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta\text{Gallons} = (\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) * L * \text{SPD} * \text{Days} * \text{ISR}$$

Variables as defined above

For example, for a direct-installed 1.5 GPM showerhead in an office open every day with where the number of showers is estimated at 3 per day:

$$\begin{aligned} \Delta\text{Gallons} &= (2.5 - 1.5) * 7.8 * 3 * 365.25 * 1.0 \\ &= 8,547 \text{ gallons} \end{aligned}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HWE-LFSH-V05-220101

SUNSET DATE: 1/1/2026

3.2.3. Hot Water Heater

DESCRIPTION

This measure is for upgrading from a minimum code water heater to either a high-efficiency storage water heater or a tankless water heater.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must meet program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a new standard water heater of same type and fuel as existing, meeting the Federal Standard provided below. If existing type is unknown, assume a storage unit with same fuel as the efficient unit.

For Residential-sized >55 gallon electric tanks, the baseline should be as provided below unless the existing tank being replaced is <55 gallon, in which case the <55 gallon algorithms should be used. This is to account for the fact that often a larger HP tank is used in place of a smaller resistance tank to take full advantage of the full HP cycle.

Note the same draw pattern (very small, low, medium and high draw) should be used for both baseline and efficient units.

Equipment Type	Sub Category	Draw Pattern	Federal Standard ¹⁹⁰
Residential-duty Commercial High Capacity Storage Gas-Fired Storage Water Heaters > 75,000 Btu/h	≤120 gallon tanks	Very small	$UEF = 0.2674 - (0.0009 * \text{Rated Storage Volume in Gallons})$
		Low	$UEF = 0.5362 - (0.0012 * \text{Rated Storage Volume in Gallons})$
		Medium	$UEF = 0.6002 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		High	$UEF = 0.6597 - (0.0009 * \text{Rated Storage Volume in Gallons})$
Commercial Gas Storage Water Heaters >75,000 Btu/h and ≤155,000 Btu/h	>120 gallon tanks	All	80% E _{thermal} , Standby Losses = $(Q / 800 + 110v \text{Rated Storage Volume in Gallons})$
Commercial Gas Storage Water Heaters >155,000 Btu/h		All	
Commercial Gas Instantaneous Water Heaters > 200,000 Btu/h	<10 gal	All	80% E _{thermal}
	≥10 gal	All	80% E _{thermal}
Residential Sized Electric Storage Water Heaters ≤ 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 ¹⁹¹	Very small	$UEF = 1.9236 - (0.0011 * \text{Rated Storage Volume in Gallons})$
		Low	$UEF = 2.0440 - (0.0011 * \text{Rated Storage Volume in Gallons})$

¹⁹⁰ Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431.

¹⁹¹ For >55 gallon tanks, the baseline should be as provided, unless the existing tank being replaced is <55 gallon, in which case the <55 gallon algorithms should be used. This is to account for the fact that often a larger HP tank is used in place of a smaller resistance tank to take full advantage of the full HP cycle.

Equipment Type	Sub Category	Draw Pattern	Federal Standard ¹⁹⁰
		Medium	UEF = 2.1171 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 2.2418 – (0.0011 * Rated Storage Volume in Gallons)

Residential-duty Commercial Water Heaters meet the following criteria:

- Is not designed to provide outlet hot water at temperatures greater than 180 °F; and
- If electric, must use a single-phase external power supply; and
- Gas-fired Storage Water Heater with a rated input no greater than 105 kBtu/h and a DOE Rated Storage volume no greater than 120 gallons.
- Electric Instantaneous with a rated input no greater than 58.6 kW and a DOE Rated Storage volume no greater than 2 gallons.

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:¹⁹²

Storage Water Heater Draw Pattern	
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	
Draw Pattern	Max GPM
Very Small	≥ 0 and < 1.7
Low	≥ 1.7 and < 2.8
Medium	≥ 2.8 and < 4
High	≥ 4

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for water heaters is assumed to be 15 years for storage heaters and 20 years for tankless water heaters.¹⁹³

DEEMED MEASURE COST

Actual costs should be used where available and if associated baseline costs can also be estimated for the application. If actual costs are unknown full install costs and incremental cost assumptions are provided below:¹⁹⁴

¹⁹² Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1.

¹⁹³ Based on assumptions for high efficiency commercial storage water heaters and instantaneous water heaters in 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014 (http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx).

¹⁹⁴ Cost information is based upon data from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. See “NR HW Heater_WA017_MCS Results Matrix - Volume I.xls” for more information. For Electric Heat Pump Water Heaters, costs for <2.6 UEF are based upon averages from the NEEP Phase 3 Incremental Cost Study; The assumption for higher

Equipment Type	Category	Install Cost	Incremental Cost
Gas Storage Water Heaters ≤ 75,000 Btu/h, ≤55 Gallons	Baseline	\$616	N/A
	Efficient	\$1,055	\$440
Gas Storage Water Heaters > 75,000 Btu/h	0.80 Et	\$4,886	N/A
	0.83 Et	\$5,106	\$220
	0.84 Et	\$5,299	\$413
	0.85 Et	\$5,415	\$529
	0.86 Et	\$5,532	\$646
	0.87 Et	\$5,648	\$762
	0.88 Et	\$5,765	\$879
	0.89 Et	\$5,882	\$996
Gas Tankless Water Heaters >50,000 Btu/h and <200,000 Btu/h	Tankless Baseline	\$593	N/A
	Efficient	\$1,080	\$487
	Incremental using Storage Baseline		\$465
Gas Tankless Water Heaters ≥200,000 Btu/h	Tankless Baseline	\$1,148	N/A
	Efficient	\$1,427	\$278
	Incremental using Storage Baseline		-\$3,459
Electric Heat Pump Water Heaters ≤55 gallons	Baseline	\$1,032	N/A
	<2.6 UEF	\$2,062	\$1,030
	≥2.6 UEF	\$2,231	\$1,199
Electric Heat Pump Water Heaters >55 gallons	Baseline	\$1,319	N/A
	<2.6 UEF	\$2,432	\$1,113
	≥2.6 UEF	\$3,116	\$1,797

LOADSHAPE

Loadshape NRGW01:16 – Nonresidential Gas Hot Water (by Building Type)

Loadshape NREW01:16 – Nonresidential Electric Hot Water (by Building Type)

efficiency tanks is based upon averaged from NEEP Phase 4 Incremental Cost Study; See 'HPWH Cost Estimation.xls' for more information.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \left(\frac{1}{UEF_{elecbase}} - \frac{1}{UEF_{Eff}} \right)}{3412} + kWh_{cool} - kWh_{heat}$$

Where:

T_{out} = Unmixed Outlet Water Temperature
 = custom, otherwise assume 140¹⁹⁵

T_{in} = Inlet Water Temperature
 = custom - otherwise assume 56.5¹⁹⁶

HotWaterUse_{Gallon} = Estimated annual hot water consumption (gallons)
 = Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

1. Consumption per usable storage tank capacity
 = Capacity * Consumption/cap

Where:

Capacity = Usable capacity of hot water storage tank in gallons
 = Actual¹⁹⁷

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:¹⁹⁸

Building Type ¹⁹⁹	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788

¹⁹⁵ Ideally the actual set point of the water heater should be used. If not, 140 degrees is provided as an estimate based on review of building and plumbing codes for IA. The codes limit temperatures at the end use but not at the water heater system, which can be anywhere in the range 120 -201 degrees. Generally speaking, code limits the temperature to fixtures to 120 degrees F and 140 degrees for applications like laundry or dishwashing.

¹⁹⁶ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. <http://www.nrel.gov/docs/fy10osti/47246.pdf>; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

¹⁹⁷ If the replaced unit is a tankless water heater, the 2nd method provided or an alternative should be used to estimate consumption.

¹⁹⁸ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data for West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

¹⁹⁹ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

Building Type ¹⁹⁹	Consumption/Cap
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	377
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multifamily	894

2. Consumption per unit area by building type
 = (Area/1000) * Consumption/1,000 sq.ft.

Where:

Area = Area in sq.ft that is served by DHW boiler
 = Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:²⁰⁰

Building Type ²⁰¹	Consumption/1,000 sq.ft.
Convenience	3,634
Education	5,440
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133

γ_{Water} = Specific weight capacity of water (lb/gal)
 = 8.33 lbs/gal

²⁰⁰ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

²⁰¹ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

- 1 = Specific heat of water (Btu/lbm/°F)
- UEF_{elecbase} = Rated efficiency of baseline water heater expressed as Uniform Energy Factor (UEF);
Note the same draw pattern (very small, low, medium and high draw) should be used for both baseline and efficient units.

Equipment Type	Sub Category	Draw Pattern	Federal Standard – Uniform Energy Factor ²⁰²
Residential Electric Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	Very small	UEF = 0.8808 – (0.0008 * Rated Storage Volume in Gallons)
		Low	UEF = 0.9254 – (0.0003 * Rated Storage Volume in Gallons)
		Medium	UEF = 0.9307 – (0.0002 * Rated Storage Volume in Gallons)
		High	UEF = 0.9349 – (0.0001 * Rated Storage Volume in Gallons)
	>55 gallon and ≤120 gallon tanks ²⁰³	Very small	UEF = 1.9236 – (0.0011 * Rated Storage Volume in Gallons)
		Low	UEF = 2.0440 – (0.0011 * Rated Storage Volume in Gallons)
		Medium	UEF = 2.1171 – (0.0011 * Rated Storage Volume in Gallons)
		High	UEF = 2.2418 – (0.0011 * 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:²⁰⁴

Storage Water Heater Draw Pattern	
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	
Draw Pattern	Max GPM
Very Small	≥ 0 and < 1.7
Low	≥ 1.7 and < 2.8
Medium	≥ 2.8 and < 4
High	≥ 4

- UEF_{eff} = Rated efficiency of efficient water heater expressed as Uniform Energy Factor (UEF)
= Actual
- 3412 = Converts Btu to kWh
- kWh_{cool} = Cooling savings from conversion of heat in building to water heat²⁰⁵

²⁰² 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.

²⁰³ For >55 gallon tanks, the baseline should be as provided, unless the existing tank being replaced is <55 gallon, in which case the <55 gallon algorithms should be used. This is to account for the fact that often a larger HP tank is used in place of a smaller resistance tank to take full advantage of the full HP cycle.

²⁰⁴ Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1.

²⁰⁵ 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.

$$= \left[\frac{\left((T_{OUT} - T_{IN}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \left(1 - \frac{1}{UEF_{Eff}} \right) \right) * LF * 18\% * LM}{COP_{COOL} * 3412} \right] * Cool$$

Where:

- LF = Location Factor
 - = 1.0 for HPWH installation in a conditioned space
 - = 0.5 for HPWH installation in an unknown location²⁰⁶
 - = 0.0 for installation in an unconditioned space
- 18% = Portion of reduced waste heat that results in cooling savings²⁰⁷
- COP_{COOL} = COP of Central Air Conditioner
 - = Actual - If unknown, assume 3.08 (10.5 SEER / 3.412)
- LM = Latent multiplier to account for latent cooling demand
 - = 1.33²⁰⁸
- Cool = 1 if building has central cooling, 0 if not cooled

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

$$= \left(\frac{\left((T_{OUT} - T_{IN}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \left(1 - \frac{1}{UEF_{Eff}} \right) \right) * LF * 24\%}{COP_{HEAT} * 3412} \right) * ElectricHeat$$

Where:

- 24% = Portion of reduced waste heat that results in increased heating load²⁰⁹
- COP_{HEAT} = COP of electric heating system
 - = Actual system efficiency including duct loss - If not available, use:²¹⁰

²⁰⁶ Note unconditioned means a space that is not intentionally heated via furnace vents or boiler radiators. The presence of and/or leakage from a heating system in a space doesn't in itself imply the space is conditioned.

²⁰⁷ This is estimated based on the percentage 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). This is based on the average WHFe for non-residential buildings (1.06) and assuming an average cooling COP of 3.08 (1.06 = 1 + 0.1848/3.08).

²⁰⁸ 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

²⁰⁹ This is estimated based on the percentage 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). The average WHFH for non-residential buildings is 24%.

²¹⁰ 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
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

ElectricHeat = 1 if building is electrically heated, 0 if not

For example, an 100 gallon 4.3 UEF Heat Pump Water heater is installed in place of a failed 100 gallon resistance tank, in a 1500 ft² restaurant with high draw rate. Unit is installed in conditioned, cooled space with gas heat:

$$\begin{aligned}
 UEF_{elecbase} &= 2.2418 - (0.0011 * \text{Rated Storage Volume in Gallons}) \\
 &= 2.2418 - (0.0011 * 50) \\
 &= 2.187 \\
 kWh_{cool} &= ((140 - 56.5) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1 - 1/4.3) * 1 * 0.18 * 1.33) / (3.08 * 3412) * 1 \\
 &= 491 \text{ kWh} \\
 kWh_{heat} &= 0 \text{ kWh} \\
 \Delta kWh &= ((140 - 56.5) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1/2.187 - 1/4.3)) / 3412 + 491 - 0 \\
 &= 2,341 \text{ kWh}
 \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- Hours = Full load hours of water heater
= 2,791²¹¹
- CF = Summer Peak Coincidence Factor for measure
= 41%²¹²

NATURAL GAS SAVINGS

$$\begin{aligned}
 \Delta Therms &= \Delta Therms_{Unit} + \Delta Therms_{standby} \\
 \Delta Therms_{Unit} &= \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \left(\frac{1}{\mu_{base}} - \frac{1}{\mu_{Eff}} \right)}{100,000}
 \end{aligned}$$

Where:

²¹¹ Water heater full load hour assumption is based on loadshape information provided by Cadmus.

²¹² Water heater coincidence factor assumption is based on loadshape information provided by Cadmus.

μ_{base} = Rated efficiency of baseline water heater

Equipment Type	Sub Category	Draw Pattern	μ_{base}^{213}
Residential-duty Commercial High Capacity Storage Gas-Fired Storage Water Heaters > 75,000 Btu/h	≤120 gallon tanks	Very small	UEF = 0.2674 – (0.0009 * V)
		Low	UEF = 0.5362 – (0.0012 * V)
		Medium	UEF = 0.6002 – (0.0011 * V)
		High	UEF = 0.6597 – (0.0009 * V)
Commercial Gas Storage Water Heaters >75,000 Btu/h and ≤155,000 Btu/h	>120 gallon tanks	All	80% E _{thermal} , Standby Losses = (Q /800 + 110vV)
Commercial Gas Storage Water Heaters >155,000 Btu/h		All	
Commercial Gas Instantaneous Water Heaters > 200,000 Btu/h	<10 gal	All	80% E _{thermal}
	≥10 gal	All	80% E _{thermal}

Where:

V = Rated storage volume of new water heater in gallons
 = Actual

Draw Pattern = Draw profile based on actual water heater size and capacity ²¹⁴

Draw Pattern	First Hour Rating (gallons)
Very Small	≥ 0 and < 18
Low	≥ 18 and < 51
Medium	≥ 51 and < 75
High	≥ 75

μ_{eff} = Rated efficiency of efficient water heater (UEF or Thermal Efficiency)
 = Actual

100,000 = Converts Btu to Therms

Additional Standby Loss Savings

Gas Storage Water Heaters >75,000 Btu/h and Gas Tankless Water Heaters ≥200,000 Btu/h and with ≥10gal tank can claim additional savings due to lower standby losses.

Note, Residential-Duty Commercial Water heaters are not eligible to claim additional standby losses savings because the Uniform Energy Factor efficiency rating includes standby loss considerations.

$$\Delta Therms_{Standby} = \frac{(SL_{base} - SL_{eff}) * 8760}{100,000}$$

Where:

SL_{base} = Standby loss of baseline unit

²¹³ Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431.

²¹⁴ 10 CFR 430, Subpart B, Appendix E, Section 5.4.1

$$= Q/800 + 110\sqrt{V}$$

Q = Nameplate input rating in Btu/h

V = Rated volume in gallons

SL_{eff} = Nameplate standby loss of new water heater, in BTU/h

8760 = Hours per year

Example - Commercial Water Heater: for a 95% Thermal Efficiency, 130,000 Btu/hr, 100 gallon storage unit with rated standby loss of 1,079 Btu/h installed in a 1,500 ft² restaurant:

$$\begin{aligned} \Delta\text{Therms}_{\text{Unit}} &= ((140 - 56.5) * ((1,500/1,000) * 26,927) * 8.33 * 1 * (1/0.8 - 1/0.95))/100,000 \\ &= 55.4 \text{ Therms} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms}_{\text{Standby}} &= (((130,000/800 + 110 * \sqrt{100}) - 1,079) * 8,760)/100,000 \\ &= 16.1 \text{ Therms} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= 55.4 + 16.1 \\ &= 71.5 \text{ Therms} \end{aligned}$$

Example - Residential-Duty Commercial Water Heater: for a 0.86 Uniform Energy Factor (UEF), 100,000 Btu/hr, 74 gallon storage unit with first hour rating of 130 gallons installed in a 6,000 ft² multifamily apartment building:

Draw Pattern = High (First hour rating > 75 gallons)

$$\begin{aligned} \text{UEF}_{\text{Base}} &= 0.6597 - (0.0009 * 74) \\ &= 0.5931 \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms}_{\text{Unit}} &= ((140 - 56.5) * ((6,000/1,000) * 13,133) * 8.33 * 1 * (1/0.5934 - 1/0.86))/100,000 \\ &= 286.3 \text{ Therms} \end{aligned}$$

$\Delta\text{Therms}_{\text{Standby}}$ = 0 – This is a Residential-Duty Commercial Water heater which does not qualify for standby loss savings

$$\Delta\text{Therms} = 286.3 \text{ Therms}$$

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:

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

Where:

ΔTherms = Therm impact calculated above

365.25 = Days per year

For example, for a 95% Thermal Efficiency, 130,000 Btu/hr, 100 gallon storage unit with rated standby loss of 1,079 BTU/h installed in a restaurant:

$$\begin{aligned} \Delta\text{PeakTherms} &= 71.5 / 365.25 \\ &= 0.1958 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Annual O&M for storage water heaters is assumed to be consistent between baseline and efficient.

The deemed O&M cost adjustment for a gas fired tankless heater is assumed to be \$100.²¹⁵

MEASURE CODE: NR-HWE-GHWH-V06-220101

SUNSET DATE: 1/1/2025

²¹⁵ Tankless Water Heaters require annual maintenance by licensed professionals to clean control compartments, burners, venting system, and heat exchangers. The incremental cost of the additional annual maintenance for tankless WH is estimated at \$100.

3.2.4. Controls for Central Domestic Hot Water

DESCRIPTION

Demand control recirculation pumps seek to reduce inefficiency by combining control via temperature and demand inputs, whereby the controller will not activate the recirculation pump unless both (a) the recirculation loop return water has dropped below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

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

Re-circulating pump shall cycle on based on (a) the recirculation loop return water dropping below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

DEFINITION OF BASELINE EQUIPMENT

The base case for this measure category is an existing, un-controlled recirculation pump on a gas-fired Central Domestic Hot Water System.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The effective useful life is 15 years.²¹⁶

DEEMED MEASURE COST

Actual material and labor costs should be used if available. If actual costs are unknown, the assumed measure cost is \$1,200 per pump.²¹⁷

LOADSHAPE

Loadshape NREW08 – Nonresidential Electric Hot Water – Multifamily

Loadshape NRGW08 – Nonresidential Gas Hot Water - Multifamily

Algorithm

CALCULATION OF ENERGY SAVINGS²¹⁸

Savings shown are per pump.

ELECTRIC ENERGY SAVINGS

Deemed at 651 kWh.²¹⁹

SUMMER COINCIDENT PEAK DEMAND SAVINGS

²¹⁶ Benningfield Group. (2009). *PY 2009 Monitoring Report: Demand Control for Multifamily Central Domestic Hot Water*. Folsom, CA: Prepared for Southern California Gas Company, October 30, 2009.

²¹⁷ Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation Public project report*. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.

²¹⁸ Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation Public project report*. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.

²¹⁹ Based on results from the Nicor Gas Emerging Technology Program study, this value is the average kWh saved per pump. Note this value does not reflect savings from electric units but electrical savings from gas-fired units.

Summer coincident peak demand savings are expected to be negligible.

NATURAL GAS SAVINGS

$$\Delta\text{Therms} = 55.9 * \text{number of dwelling units}$$

Where:

$$55.9 = \text{Therms saved per dwelling unit}^{220}$$

$$\begin{aligned} \text{Number of dwelling units} &= \text{Number of dwelling units at the site} \\ &= \text{Actual} \end{aligned}$$

For example, an apartment building with 53 units:

$$\begin{aligned} \Delta\text{Therms} &= 55.9 * 53 \\ &= 2,962.7 \text{ therms} \end{aligned}$$

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:

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

Where:

$$\Delta\text{Therms} = \text{Therm impact calculated above}$$

$$365.25 = \text{Days per year}$$

For example, an apartment building with 53 units:

$$\begin{aligned} \Delta\text{PeakTherms} &= 2,962.7 / 365.25 \\ &= 8.11 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HWE-DHWC-V03-230101

SUNSET DATE: 1/1/2025

²²⁰ Based on results from the Nicor Gas Emerging Technology Program study, this value is the average therms saved per dwelling unit.

3.2.5. Pool Covers

DESCRIPTION

This measure refers to the installation of covers on commercial use pools that are heated with gas-fired equipment. By installing pool covers, the heating load on the pool boiler will be reduced by reducing the heat loss from the water to the environment and the amount of actual water lost due to evaporation (which then requires additional heated water to make up for it).

The main source of energy loss in pools is through evaporation. This is particularly true of outdoor pools where wind plays a larger role. The point of installing pool covers is threefold. First, it will reduce convective losses due to the wind or air movement by shielding the water surface. Second, it will insulate the water from the colder surrounding air. And third, it will reduce radiative losses to the night sky (for outdoor pools). In doing so, evaporative losses will also be minimized, and the boiler will not need to work as hard in replenishing the pool with hot water to keep the desired temperature.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is the installation of a pool cover with a 5 year warranty.

DEFINITION OF BASELINE EQUIPMENT

The base case is a pool that is uncovered.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The useful life of this measure is assumed to be 6 years.²²¹

DEEMED MEASURE COST

For retrofits, actual material and labor costs should be used if available. If actual costs are unknown, use the following costs based on square footage and whether the cover is manually operated or automatic:

\$ / Sqft ²²²	
Manually Operated	Automatic
\$1.50	\$6.50

LOADSHAPE

Loadshape NRGW01:16 – Nonresidential Gas Hot Water (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

²²¹ The effective useful life of a pool cover is typically one year longer than its warranty period. SolaPool Covers. Pool Covers Website, FAQ- "How long will my SolaPool cover blanket last?". Pool covers are typically offered with 3 and 5 year warranties with at least one company offering a 6 year warranty. Conversation with Trade Ally. Knorr Systems

²²² Based on the average costs used by the U.S. DOE's Energy Smart Pools software

Note: indoor pool covers may also save electricity due to positive interactions with the building’s HVAC system. However, since these interactions are very site dependent, a custom calculation should be used to determine impact.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{\sum_{Season}(Savings\ Factor) * Sqft}{\eta_{heat}}$$

Where

Savings Factor = dependant on season and location:²²³

Season and Location	Savings Factor (Therms / ft ²)
Spring	0.37
Summer	0.21
Fall	0.77
Winter	0.92
Year-round	2.27
Indoor	0.9

Sqft = surface area of the pool in ft²

= Actual

η_{heat} = Efficiency of gas heating system

= Actual

PEAK GAS SAVINGS

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

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

Where:

$\Delta Therms$ = Therm impact calculated above

Days = Days in operating season

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

Water savings result from a reduction in evaporative losses:

$$\Delta Gallons = \frac{Sqft * h_{makeup} * Freq * 7.48052 * 0.3}{12}$$

Where:

²²³ The calculations are based on modeling runs using Energy Smart Pools Software that was created by the U.S. Department of Energy. See Commercial Pool Cover Calcs.xlsx for additional details.

Sqft	= surface area of the pool in ft ²
	= Actual
h_{makeup}	= Height, in inches, the pool is typically filled when make-up water is added
	= Actual
Freq	= Total number of water make-up events throughout the operating season
	= Actual
7.48052	= gallons of water per ft ³
12	= inches per foot
0.3 ²²⁴	= conservative estimate for the reduction of make-up water required

DEEMED O&M COST ADJUSTMENT CALCULATION

There are no O&M cost adjustments for this measure.

MEASURE CODE: NR-HWE-PCOV-V02-180101

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.

²²⁴ As listed on <http://energy.gov/energysaver/swimming-pool-covers>

3.2.6. Drainwater Heat Recovery

DESCRIPTION

Drain-water (or greywater) heat recovery systems capture and reuse energy from a drainpipe to preheat incoming cold water, thereby reducing the amount of energy needed for domestic water heating. The heat recovery device typically consists of a wound copper heat exchanger that replaces a vertical section of a main waste drain. As warm water flows down the waste drain, incoming cold water flows through a spiral copper tube wrapped tightly around the section of the waste drain, preheating the incoming cold water.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is installation of a drainwater heat recovery device.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is no drainwater heat recovery system.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for recovery devices is 30 years.²²⁵

DEEMED MEASURE COST

Actual installation costs should be used, as cost will be related to the length of the installed device.

LOADSHAPE

Loadshape NREW01:16 – Nonresidential Electric Hot Water (by building type)

Loadshape NRGW01:16 – Nonresidential Gas Hot Water (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For sites with electric DHW:

$$\Delta kWh = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \eta_{PRA}}{3,412 * RE_{electric}}$$

Where:

T_{out} = Unmixed Outlet Water Temperature from the DHW system
 = Actual, otherwise assume 140²²⁶

²²⁵ 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.

²²⁶ Ideally the actual set point of the water heater should be used. If not, 140 degrees is provided as an estimate based on review of building and plumbing codes for IA. The codes limit temperatures at the end use but not at the water heater system,

T_{in} = Inlet Water Temperature to the DHW system
 = Actual, otherwise assume 56.5²²⁷

HotWaterUse_{Gallon} = Estimated annual hot water consumption (gallons)
 = Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

1. Consumption per usable storage tank capacity
 = Capacity * Consumption/cap

Where:

Capacity = Usable capacity of hot water storage tank in gallons
 = Actual

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type.²²⁸

Building Type ²²⁹	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	377
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multifamily	894

2. Consumption per unit area by building type
 = (Area/1000) * Consumption/1,000 sq.ft.

Where:

Area = Area in sq.ft that is served by DHW boiler

which can be anywhere in the range 120 -201 degrees. Generally speaking, code limits the temperature to fixtures to 120 degrees F and 140 degrees for applications like laundry or dishwashing.

²²⁷ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. <http://www.nrel.gov/docs/fy10osti/47246.pdf>; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

²²⁸ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data for West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

²²⁹ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

= Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:²³⁰

Building Type ²³¹	Consumption/1,000 sq.ft.
Convenience	3,634
Education	5,440
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133

γ_{Water} = Specific weight capacity of water (lb/gal)
= 8.33 lbs/gal

1 = Specific heat of water (Btu/lbm/°F)
= Actual

η_{PRA} = Practical effectiveness of drainwater heat recovery (percentage of DHW output energy that the device can recover)
= 25%.²³² Note: practical effectiveness is generally lower than the effectiveness reported by manufacturers, which assume steady state operation, typically with equal flow rates. In practice, however, flow rates are rarely steady state and are unequal, and as a result effectiveness is constantly changing. Practical effectiveness can therefore be thought of the time-averaged value of effectiveness and could only be definitely determined through on-site data collection.

3,412 = Conversion from Btu to kWh

RE_{electric} = Recovery efficiency of electric DHW system

²³⁰ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of West North Central (removed outliers of 1,000 kBtu/h or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

²³¹ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

²³² Metering study found savings to range from 25% to 30%. Assume 25% savings for this analysis and interpolated from graph of Figure 2. Heating contributions depend on inlet water temperature (page 3) based on: Tomlinson, J. J. Letter to Marc LaFrance, Manager, Appliance and Emerging Technology Program, US Department of Energy. Subject: GFX Evaluation. Oak Ridge, TN: Oak Ridge National Laboratory, accessed 07 November 2008, <http://gfxtechnology.com/Duluth-Triplex.pdf>. With reference to "A Quantitative Study of the Viability of Greywater Heat Recovery (GWHR)", June 2011

- = Actual if known - if not, assume:
- = 98% for electric resistance ²³³
- = 200% for heat pump water heaters ²³⁴

For example, for an electric DHW system with a 100 gallon storage unit and a recovery efficiency of 98% installed in a restaurant:

$$\begin{aligned} \Delta kWh &= (140 - 56.5) * (377 * 100) * 8.33 * 1 * 0.25 / (3,412 * 0.98) \\ &= 1,960.5 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- Hours = 8,760
- CF = Summer Peak Coincidence Factor for measure
- = 41%²³⁵

For example, for an electric DHW system with a 100 gallon storage unit and a recovery efficiency of 98% installed in a restaurant:

$$\begin{aligned} \Delta kW &= 1,960.5 / 8,760 * 0.41 \\ &= 0.0918 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

For sites with natural gas DHW:

$$\Delta Therms = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \eta_{PRA}}{100,000 * RE_{gas}}$$

Where:

- 100,000 = Converts Btu to Therms
- RE_{gas} = Recovery efficiency of gas DHW system
- = Actual if known - if not, assume:
- = 78% for buildings with storage tank, 59% if hot water through central boiler, or 69% if unknown²³⁶

²³³ Electric water heaters have recovery efficiency of 98%: <https://www.ahridirectory.org/Search/SearchHome>

²³⁴ 200% 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.

²³⁵ Coincidence factor is in line with the Residential Hot Water measure, 3.2.3.

²³⁶ 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 water heating system is unknown. Commercial properties are often

Other terms as defined above.

For example, for a natural gas DHW system with a 100 gallon storage unit and a recovery efficiency of 85% installed in a restaurant:

$$\begin{aligned} \Delta\text{Therms} &= (140 - 56.5) * (377 * 100) * 8.33 * 1 * 0.25 / (100,000 * 0.85) \\ &= 77.1 \text{ Therms} \end{aligned}$$

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:

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

Where:

- ΔTherms = Therm impact calculated above
- 365.25 = Days per year

For example, for a natural gas DHW system with a 100 gallon storage unit and a recovery efficiency of 85% installed in a restaurant:

$$\begin{aligned} \Delta\text{PeakTherms} &= 77.1 / 365.25 \\ &= 0.2111 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

There are no operation and maintenance costs associated with this measure.

MEASURE CODE: NR-HWE-DWHR-V04-230101

SUNSET DATE: 1/1/2026

provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .78 for single family home. An average is used for this analysis by default.

3.3. Heating, Ventilation, and Air Conditioning (HVAC)

Many of the Nonresidential HVAC measures use equivalent full load hours (EFLH) to calculate heating and cooling savings. The tables with these values are included in this section and referenced in each measure. Values for both existing and new construction buildings are provided.

To calculate the EFLH by building type and climate zone provided below, VEIC created models (using OpenStudio or eQuest as available) for each building type. The EFLH calculation is based on hourly building loads (total heating/cooling output). The calculation allows for a more generally applicable EFLH determination that is tied to the load profiles of various building prototypes and not affected by modeling irregularities that can be equipment specific. The load profiles are related to system characteristics such as constant vs. variable air volume and single- vs. multi-zone configurations, but not sensitive to how the energy model treats equipment operation at very low loads or performs sizing estimates. The calculation is the annual total (heating or cooling) output (in Btu) divided by the 95th percentile hourly peak output (heating or cooling) demand (in Btu/hr). This keeps EFLH independent of modeled equipment efficiency (which is accounted for in the TRM savings calculation) and energy model sizing. It also buffers EFLH value from hourly variances in the modeling that are not representative of actual buildings.

The OpenStudio and eQuest models, prototype building descriptions, methodology documentation, and final results can be found on the Iowa TRM SharePoint Site (TRM Reference Documents/ Non Residential/ Modeling).

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be used. For the specific assumptions used in each model, refer to table in the [“IA Prototype Building Descriptions”](#) file in the SharePoint folder referenced above.

Existing Building

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average / Unknown		Weighting Factors for Nonresidential Average ²³⁷	Model Source
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH		
Education	1298	1073	1529	848	1351	928	9%	OpenStudio
Grocery	1493	320	1754	221	1601	356	0%	OpenStudio
Health	1206	1449	1430	996	1346	1207	0%	OpenStudio
Hospital	1084	1792	940	1436	1082	1662	0%	OpenStudio
Lodging	1365	1464	1464	1252	1494	1460	0%	OpenStudio
Multifamily	1521	1472	1846	1045	1694	1349	0%	OpenStudio
Office - Large	1457	1141	1748	843	1549	1084	0%	OpenStudio
Office - Small	1250	986	1435	667	1358	882	26%	OpenStudio
Restaurant	1040	1397	1324	937	1173	1249	7%	OpenStudio
Retail - Large	1255	846	1523	616	1348	845	5%	OpenStudio
Retail - Small	1172	891	1471	531	1372	780	11%	OpenStudio
Warehouse	1277	1032	1589	539	1443	864	26%	OpenStudio

²³⁷ The weighting used to average modeled variables into a generic, nonresidential category is based on the number of buildings matching each building type in the 2012 Commercial Buildings Energy Consumption Survey (CBECS) Data for the Midwest Region, West North Central Division, which includes Iowa. Building types that comprise less than 5% of the total population are excluded from the weighted averaging. Values rounded in table, see model reference files for exact values.

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average / Unknown		Weighting Factors for Nonresidential Average ²³⁷	Model Source
Convenience	785	1477	1224	1128	1071	1351	0%	eQuest
Industrial	849	1185	1275	856	1183	1063	0%	eQuest
Religious	1322	1109	1873	797	1796	1031	16%	eQuest
Nonresidential Average	1251	1034	1555	669	1438	915	N/A	N/A

New Construction

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average / Unknown		Weighting Factors for Nonresidential Average ²³⁸	Model Source	
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH			
Education	510	776	683	464	591	645	11%	OpenStudio	
Health	778	1482	972	1073	864	1328	0%	OpenStudio	
Hospital	1799	1422	1520	946	2196	1356	0%	OpenStudio	
Lodging	1080	1204	1491	813	1471	1105	0%	OpenStudio	
Office - Large	710	816	917	641	862	823	0%	OpenStudio	
Office - Small	450	616	590	448	492	542	31%	OpenStudio	
Restaurant	896	915	1192	572	1048	825	8%	OpenStudio	
Retail - Large	709	764	906	504	839	711	6%	OpenStudio	
Retail - Small	785	749	1036	486	986	744	13%	OpenStudio	
Warehouse	886	223	1238	35	1116	148	31%	OpenStudio	
Convenience	N/A ²³⁹								
Industrial									
Religious									
Grocery									
Multifamily									
Nonresidential Average	690	560	930	338	830	488	N/A	N/A	

²³⁸ The weighting used to average modeled variables into a generic, nonresidential category is based on the number of buildings matching each building type in the 2012 Commercial Buildings Energy Consumption Survey (CBECS) Data for the Midwest Region, West North Central Division, which includes Iowa. Building types that comprise less than 5% of the total population are excluded from the weighted averaging. Note: weighting is different than that for Existing Building due to exclusion of building types with “N/A” values.

²³⁹ Constraints related to prototype building information availability results in New Construction assumptions being unavailable for these building types. These building types will be added in a future cycle when prototype information becomes available.

3.3.1. Boiler

DESCRIPTION

To qualify for this measure, the installed equipment must be a replacement for an existing boiler at the end of its service life, in a nonresidential or multifamily space with a high efficiency, gas-fired hot water boiler. High efficiency condensing boilers achieve 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 gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, some of the flue gasses condense and must be drained. This measure is limited to boilers providing space heat only or combined space and DHW, and not DHW only boilers.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a natural gas condensing boiler used for space heating, not process, and boiler efficiency rating must meet the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency source is a natural gas non-condensing boiler used for space heating, not process, meeting the federal equipment standards. The Federal Standard applicable to commercial boilers imported to, or manufactured in, the United States prior to January 10, 2023, designates a minimum AFUE rating of 84% for boilers <300,000 Btu/hr capacity,²⁴⁰ 80% E_T for boilers $\geq 300,000$ Btu/h and $\leq 2,500,000$ Btu/h, and 82% E_C for boilers $> 2,500,000$ Btu/h.²⁴¹

New manufacturing federal energy conservation standards for commercial packaged boilers went into effect on January 10, 2023. This measure characterization adopted these standards as the baseline on 1/1/2024. As a result the [baseline now meets the Federal Standard minimum efficiency ratings of 84% AFUE for boilers <300,000 Btu/hr capacity, 84% \$E_T\$ for boilers \$\geq 300,000\$ Btu/h and \$\leq 2,500,000\$ Btu/h, and 85% \$E_C\$ for boilers \$> 2,500,000\$ Btu/h.](#)²⁴²

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.²⁴³

DEEMED MEASURE COST

The incremental install cost for boilers with <300,000 Btu/hr input capacity is provided in the table below and is dependent on AFUE efficiency.²⁴⁴ Any boiler $\geq 300,000$ Btu/h input capacity shall use a custom cost input.

AFUE	Full Install Cost	Incremental Install Cost
84%	\$5,635	n/a

²⁴⁰ [Code of Federal Regulations, 10 CFR 430.32\(e\)\(2\)\(iii\)\(A\)](#)

²⁴¹ Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

²⁴² [Code of Federal Regulations, 10 CFR 431.87, Table 2 – Commercial Packaged Boiler Energy Conservation Standards](#)

²⁴³ [U.S. Department of Energy, “Chapter 8. Life Cycle Cost and Payback Period Analysis,” ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT: COMMERCIAL WATER HEATING EQUIPMENT, April 2022. Table 8.2.16](#)

²⁴⁴ [Based on data provided in U.S. Department of Energy, “Chapter 8. Life Cycle Cost and Payback Period Analysis,” ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT: COMMERCIAL WATER HEATING EQUIPMENT, April 2022. Table 8.4.20. See “3.3.1 Version 8 Boiler DOE Chapter 8 Cost Info.xlsx” for more information.](#)

AFUE	Full Install Cost	Incremental Install Cost
85%	\$5,891	\$256
86%	\$6,123	\$488
87%	\$6,356	\$721
88%	\$6,588	\$953
89%	\$6,820	\$1,185
90%	\$7,053	\$1,418
91%	\$7,285	\$1,650
92%	\$7,517	\$1,882
93%	\$7,750	\$2,115
94%	\$8,124	\$2,489
95%	\$8,214	\$2,579
96%	\$8,328	\$2,693
97%	\$8,679	\$3,044
98%	\$8,911	\$3,276
99%	\$9,143	\$3,508

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

LOADSHAPE

Loadshape NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Loadshape NRGB01:16 – Nonresidential Gas Heat and Hot Water (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta_{Therms} = \frac{EFLH * Capacity * \left(\frac{EfficiencyRating (EE)}{EfficiencyRating(base)} - 1 \right)}{100,000}$$

Where:

- EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
- Capacity = Nominal Heating Input Capacity Boiler Size (Btu/hr) for efficient unit, not existing unit
- = Actual
- EfficiencyRating(base) = Baseline equipment efficiency rating, depending on boiler input capacity.

Boiler Input Capacity	Efficiency Rating
<300,000 Btu/hr	84% AFUE ²⁴⁵
≥300,000 Btu/h and ≤2,500,000 Btu/h	84% E _T ²⁴⁶
>2,500,000 Btu/h	85% E _C ²⁴⁷

EfficiencyRating(EE) = Efficient equipment efficiency rating

= Actual

100,000 = Conversion of Btu to Therms

For example, for a 150,000 Btu/hr water boiler meeting AFUE 90% in at an existing large office building in unknown location:

$$\Delta\text{Therms} = 1549 * 150,000 * ((0.90/0.84)-1) / 100,000$$

$$= 166.0 \text{ Therms}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ²⁴⁸	Model Source
Convenience	1.631%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4240%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1745%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ²⁴⁹	1.4623%	N/A

²⁴⁵ Code of Federal Regulations, 10 CFR 430.32(e)(2). <http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol3/pdf/CFR-2011-title10-vol3-sec430-32.pdf>. Future energy conservation standards are under development.

²⁴⁶ Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

²⁴⁷ Combustion Efficiency. Code of Federal Regulations, 10 CFR 431.87

²⁴⁸ Calculated as the percentage of total savings in the maximum saving day, from models.

²⁴⁹ For weighting factors, see HVAC variable table in section 3.3.

For example, for a 150,000 Btu/hr water boiler meeting AFUE 90% at an existing large office building in unknown location:

$$\begin{aligned}\Delta\text{Peak Therms} &= 166.0 * 0.013082 \\ &= 2.1711 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-BOIL-V05-240101

SUNSET DATE: 1/1/2028

3.3.2. Furnace

DESCRIPTION

This measure covers the installation of a high efficiency gas furnace in a nonresidential or multifamily application. High efficiency condensing gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, most of the flue gasses condense and must be drained. Furnaces equipped with ECM fan motors can save additional electric energy. ECM furnace fan is a separate measure.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a condensing furnace with input energy <225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline for this measure is a non-condensing furnace with input energy <225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating of 85%.²⁵⁰

DEFINITION OF MEASURE LIFE

The expected equipment measure life is assumed to be 18 years.²⁵¹

DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below:²⁵²

AFUE	Full Install Cost	Incremental Install Cost
85%	\$4,030	N/A
86%	\$4,086	\$56
87%	\$4,143	\$113
88%	\$4,199	\$169
89%	\$4,256	\$226
90%	\$4,312	\$282
91%	\$4,369	\$339
92%	\$4,425	\$395
93%	\$4,482	\$452
94%	\$4,538	\$508
95%	\$4,595	\$565

²⁵⁰ The Federal Standard of 80% (Code of Federal Regulations, 10 CFR 430.32(e)(2)) 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.

²⁵¹ Based on 'ASHRAE Equipment Life Expectancy chart'.

²⁵² Based on data provided by MidAmerican in April 2018 summarizing survey results from 11 HVAC suppliers. Full install costs are interpolated from data provided in the 2018 MA 'Water Heating, boiler and Furnace Cost Study' and adjusted from MA to IA costs using the 2016 implicit regional price deflators from the Bureau of Economic Analysis. See "Iowa Incremental Cost Study2_Adjusted.xls" for more information.

AFUE	Full Install Cost	Incremental Install Cost
96%	\$4,888	\$858
97%	\$5,181	\$1,151
98%	\$5,474	\$1,444
99%	\$5,768	\$1,738

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

LOADSHAPE

Loadshape NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{eff}}{AFUE_{base}} - 1 \right)}{100,000}$$

Where:

- EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use. If building type unknown (e.g. mid or upstream) assume Non-Residential average.
- Capacity = Nominal Heating Input Capacity Furnace Size (Btu/hr) for efficient unit, not existing unit
= Actual
- AFUE_{eff} = Annual Fuel Utilization Efficiency Rating (AFUE) of Energy Efficient equipment.
= Actual
- AFUE_{base} = Annual Fuel Utilization Efficiency Rating (AFUE) of Baseline equipment
= 85%
- 100,000 = Conversion of Btu to Therms

For example, for a 150,000 Btu/hr 92% efficient furnace installed at an existing small office building in unknown location:

$$\begin{aligned} \Delta Therms &= (1358 * 150,000 * (0.92/0.85 - 1)) / 100,000 \\ &= 167.8 Therms \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ²⁵³	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ²⁵⁴	1.4658%	N/A

For example, for a 150,000 Btu/hr 92% efficient furnace installed stallation at an existing small office building in unknown location:

$$\begin{aligned} \Delta PeakTherms &= 167.8 * 0.0167180 \\ &= 2.8053 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-FRNC-V06-230101

SUNSET DATE: 1/1/2025

²⁵³ Calculated as the percentage of total savings in the maximum saving day, from models.

²⁵⁴ For weighting factors see HVAC variable table in section 3.3.

3.3.3. Furnace Blower Motor

DESCRIPTION

A furnace is purchased, or retrofitted, with a brushless permanent magnet (BPM) blower motor installed instead of one with a lower efficiency motor. This measure characterizes only the electric savings associated with the fan during the heating season. Savings decrease sharply with static pressure so duct improvements, and clean, low pressure drop filters can maximize savings. Savings improve when the blower is used for cooling as well and when it is used for continuous ventilation, but only if the non-BPM motor would have been used for continuous ventilation too. If the customer runs the BPM blower continuously because it is a more efficient motor and would not run a non-BPM motor that way, savings are near zero and possibly negative.

This measure was developed to be applicable to the following program types: TOS, RF, 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. NOTE: Code of Federal Regulations applying to furnaces having a heat input rate of less than 225,000 Btu/hr and meeting definitions of the Residential Product Class effectively prohibits the manufacture of equipment utilizing non-BPM motors on and after July 3, 2019. By January 1, 2020 it shall be assumed that all equipment available for sale conforms to this regulation and therefore ineligible to claim savings for this measure. Given that the expected market for this measure could potentially rely on the Residential Product Class of furnaces for heating, care should be taken to ensure savings are claimed only for eligible equipment, i.e., furnaces that fall into the Commercial Product Class.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Measure life is deemed to be the remaining useful life of the furnace, as calculated by 20 years²⁵⁵ minus furnace age.

DEEMED MEASURE COST

If this measure is coupled with 3.3.2 Furnace, the cost of the efficient fan is assumed to be included in the cost of the furnace and can therefore be taken as \$0. As a stand-alone measure, cost is calculated as follows:

For TOS and NC projects, the incremental cost is calculated as follows:

$$\text{Cost} = -\$0.09 * \text{Watts} + \$175.8^{256}$$

Where:

Watts = Nominal wattage of the efficient motor

For retrofit applications, the actual cost of labor plus materials should be used for screening purposes.

LOADSHAPE

²⁵⁵ Consistent with assumed life of a new gas furnace. Table 8.3.3 The Technical support documents for federal residential appliance standards: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf

²⁵⁶ Incremental costs established by comparing prices as listed on grainger.com, reviewed April 2022. See "ECM costs_2022.xlsx" for complete analysis methodology.

Loadshape NREH01:16 - Nonresidential Electric Heat (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{HP * 0.746 * LF_{base} * Hours * SF}{\eta_{basemotor}}$$

Where:

- HP = Nominal horsepower of efficient motor
= Actual
- 0.746 = converts HP to kW
- LF_{base} = Load Factor of baseline motor at fan design CFM
= 65%²⁵⁷
- Hours = Annual motor operating hours
= 4000²⁵⁸
- SF = Savings factor
= 0.2²⁵⁹
- η_{basemotor} = Efficiency rating of the baseline motor
= 0.85²⁶⁰

SUMMER COINCIDENT PEAK DEMAND SAVINGS

There are no expected summer coincident peak demand savings for this measure.

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

²⁵⁷ Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). “Improving Motor and Drive System Performance; A Sourcebook for Industry”. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Golden, CO: National Renewable Energy Laboratory.

²⁵⁸ Total number of hours furnaces are expected to be operating during the heating season. Considered a conservative estimate, based on modeling results for Small Offices, Religious, Warehouse, Small Retail and Restaurants, which cumulatively represent the majority of expected market.

²⁵⁹ Based on analysis of the complete dataset in the AHRI Residential Furnaces directly, which contains over 10,000 product testing results. Analysis outlined in “AHRI res furnaces” shows that furnaces equipped with ECM motors consistently consumed about half the annual auxiliary energy compared to furnaces equipped with non-ECM motors of similar size. Considering C&I motors will typically be larger and therefore have higher baseline efficiencies, this savings factor is estimated to be .2 for C&I applications.

²⁶⁰ Engineering judgment and considered a conservative estimate, based on the NEMA Premium Efficiencies for 1 HP motors, the highest class of which is 85.5% efficient. Many ECM motors and their baseline counterparts have fractional horsepower ratings, which will have even lower efficiencies.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-FBLM-V04-230101

SUNSET DATE: 1/1/2026

3.3.4. Heat Pump Systems

DESCRIPTION

This measure applies to the installation of high-efficiency air cooled and water source heat pump systems. This measure could apply to replacing an existing unit at the end of its useful life, or installation of a new unit in a new or existing building

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

In order for this characterization to apply, the efficient equipment is assumed to be a high-efficiency air cooled, water source, ground water source, or ground source heat pump system that exceeds the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air cooled, or water source that meets the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012. New Federal Standards affecting packaged heat pumps become effective January 1, 2023.

The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.²⁶¹

DEEMED MEASURE COST

For analysis purposes, the incremental capital cost for air-cooled units is assumed to be \$467.99 per ton for up to and including CEE Tier 1 class products,²⁶² and \$935.98 per ton for CEE Tier 2 and higher class products.²⁶³ The incremental cost for all other equipment types should be determined on a site-specific basis.

LOADSHAPE

Loadshape NREP01:16 - Nonresidential Electric Heat Pump (by Building Type)

Algorithm

CALCULATION OF SAVINGS

Note: The Code of Federal Regulations mandates that manufacturers comply with minimum efficiency standards for certain types of heat pump equipment. Due to the fact that all equipment available for purchase must comply with this regulation, the Code of Federal Regulation shall be taken as the principle authoritative source for specification of baseline efficiency where applicable. Only in instances where equipment types or efficiency values are not specified by the Code of Federal Regulations shall they be sourced from IECC 2012.

²⁶¹ Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

²⁶² For specification details see; <https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0>

²⁶³ NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = [\text{Annual kWh Savings}_{cool}] + [\text{Annual kWh Savings}_{heat}]$$

For units with cooling capacities less than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}} \right)}{1000} \right] + \left[\frac{EFLH_{heat} * Capacity_{heat} * \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}} \right)}{1000} \right]$$

For units with cooling capacities less than 65 kBtu/hr using the M1 Testing Method:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{SEER2_{base}} - \frac{1}{SEER2_{ee}} \right)}{1000} \right] + \left[\frac{EFLH_{heat} * Capacity_{heat} * \left(\frac{1}{HSPF2_{base}} - \frac{1}{HSPF2_{ee}} \right)}{1000} \right]$$

Where:

- EFLH_{cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use.
- Capacity_{cool} = Cooling output capacity of Air Source Heat Pump (Btu/hr)
= Actual (where 1 ton = 12,000Btu/hr)
- SEER_{base} = Seasonal Energy Efficiency Ratio of the baseline equipment; see table below for values.²⁶⁴
- SEER_{ee} = Seasonal Energy Efficiency Ratio of the energy efficient equipment.
= Actual installed
- SEER2_{base} = Seasonal Energy Efficiency Ratio 2 of the baseline equipment; see table below for values.
- SEER_{ee} = Seasonal Energy Efficiency Ratio 2 of the energy efficient equipment.
= Actual installed
- EFLH_{heat} = heating mode equivalent full load hours are provided in section 3.3 HVAC End Use.
- Capacity_{heat} = Heating output capacity of Air Source Heat Pump (Btu/hr)
= Actual (where 1 ton = 12,000Btu/hr)
- HSPF_{base} = Heating Seasonal Performance Factor of the baseline equipment; see table below for values.
- HSPF_{ee} = Heating Seasonal Performance Factor of the energy efficient equipment.
= Actual installed
- HSPF2_{base} = Heating Seasonal Performance Factor 2 of the baseline equipment; see table below for values.

²⁶⁴ Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

HSPF2_{ee} = Heating Seasonal Performance Factor 2 of the energy efficient equipment.
 = Actual installed

For units with cooling capacities equal to or greater than 65 kBtu/hr and all water source units:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{E_{base}} - \frac{1}{E_{ee}} \right)}{1000} \right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{COP_{base}} - \frac{1}{COP_{ee}} \right)}{3412} \right]$$

Where:

E_{base} = Baseline equipment efficiency. Use Integrated Energy Efficiency Ratio (IEER), except in instances of water source units, where Energy Efficiency Ratio (EER2) shall be used; see the table below for values.

E_{ee} = Efficient equipment efficiency.
 = Actual installed. Use Integrated Energy Efficiency Ratio (IEER), except in instances of water source units, where Energy Efficiency Ratio 2 (EER2) shall be used.

3,412 = kBtu per kWh.

COP_{base} = coefficient of performance of the baseline equipment; see table below for values.

COP_{ee} = coefficient of performance of the energy efficient equipment.
 = Actual installed

All other variables as defined above.

Reminder: IECC 2012 shall only source minimum efficiency requirements when not specified by the Code of Federal Regulations.

Code of Federal Regulations: Table 3 to §431.97—Updates to the Minimum Cooling Efficiency Standards for Air Conditioning and Heating Equipment and Table 4 to §431.97—Updates to the Minimum Heating Efficiency Standards for Air-Cooled Air Conditioning and Heating Equipment [Heat Pumps]

Equipment type	Cooling capacity	Heating type	Cooling Efficiency level	Heating Efficiency level	Compliance date
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.2 IEER = 14.1	N/A	1/1/2018 1/1/2023
		All Other Types of Heating	IEER = 12.0 IEER = 13.9	COP = 3.3 COP = 3.4	1/1/2018 1/1/2023
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 11.6 IEER = 13.5	N/A	1/1/2018 1/1/2023
		All Other Types of Heating	IEER = 11.4 IEER = 13.3	COP = 3.2 COP = 3.3	1/1/2018 1/1/2023
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 10.6 IEER = 12.5	N/A	1/1/2018 1/1/2023
		All Other Types of Heating	IEER = 10.4 IEER = 12.3	COP = 3.2	1/1/2018 1/1/2023
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/h	All	SEER2 = 14.3 (SEER = 15)	HSPF2 = 7.5 (HSPF = 8.8)	1/1/2023
Small Commercial Package Air-Conditioning and Heating	<65,000Btu/h	All	SEER2 = 13.4 (SEER = 14)	HSPF2 = 6.7 (HSPF = 8)	1/1/2023

Equipment type	Cooling capacity	Heating type	Cooling Efficiency level	Heating Efficiency level	Compliance date
Equipment (Air-Cooled, 3-Phase, Single-Package)					
Small Commercial Packaged Air-Conditioning and Heating Equipment (Water Source: Water-to-Air, Water-Loop)	<17,000 Btu/h	All	EER = 12.2	COP = 4.3	10/9/2015
	≥17,000 Btu/h and <65,000 Btu/h	All	EER = 13.0	COP = 4.3	10/9/2015
	≥65,000 Btu/h and <135,000Btu/h	All	EER = 13.0	COP = 4.3	10/9/2015

IECC 2012 Specifications:

TABLE C403.2.3(2)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE*
Air cooled (cooling mode)	< 65,000 Btu/h ^b	All	Split System	13.0 SEER	AHRI 210/240
			Single Packaged	13.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h ^b	All	Split System	13.0 SEER	
			Single Packaged	13.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h ^b	All	Split System	10.0 SEER	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water source (cooling mode)	< 17,000 Btu/h	All	86°F entering water	11.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	12.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	12.0 EER	
Ground water source (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.2 EER	
		All	77°F entering water	13.4 EER	
Water-source water to water (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	
			59°F entering water	16.3 EER	
Ground water source Brine to water (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	
Air cooled (heating mode)	< 65,000 Btu/h ^b	—	Split System	7.7 HSPF	AHRI 210/240
		—	Single Package	7.7 HSPF	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h ^b (cooling capacity)	—	Split System	7.4 HSPF	
		—	Single Package	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h ^b	—	Split System	6.8 HSPF	

(continued)

TABLE C403.2.3(2)—continued
 MINIMUM EFFICIENCY REQUIREMENTS:
 ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE*
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.3 COP	AHRI 340/360
			17°F db/15°F wb Outdoor Air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.2 COP	
			17°F db/15°F wb Outdoor Air	2.05 COP	
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.2 COP	ISO 13256-1
Ground water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.6 COP	
Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.1 COP	
Water-source water to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
		—	50°F entering water	3.1 COP	
Ground source brine to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

For example, a single package 5 ton cooling unit at an existing restaurant in unknown location with 60,000 Btu/h heating capacity with a SEER2 of 15 and an HSPF2 of 9 saves

$$= [(60,000) * [(1/13.4) - (1/15)] * 1249] + [(60,000) * [(1/6.7) - (1/9)] * 1173]/1000$$

$$= 3,281 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right)}{1000} \right] * CF$$

Where:

Capacity_{Cool} = Cooling output capacity of Air Source Heat Pump (Btu/hr)
 = Actual (where 1 ton = 12,000Btu/hr)

EER_{base} = Energy Efficiency Ratio of the baseline equipment; see the tables above for values. Since EER requirements for air-cooled heat pumps < 65 kBtu/hr are not specified, assume the following conversion from SEER to EER: EER = -0.02 x SEER² + 1.12 x SEER.

EER_{ee} = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled air conditioners < 65 kBtu/hr, if the actual EER_{ee} is unknown, assume the following conversion from SEER to EER: EER = -0.02 x SEER² + 1.12 x SEER.

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ²⁶⁵	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ²⁶⁶	92.3%	N/A

For example a 5 ton cooling unit at an existing restaurant in unknown location with 60,000 Btu/h heating capacity with an EER of 14 and an HSPF of 9 saves

$$\begin{aligned} \Delta kW &= [(60,000) * [(1/11.76) - (1/12.3)]]/1000 * .996 \\ &= 0.22 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-HPSY-V06-240101

SUNSET DATE: 1/1/2026

²⁶⁵ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

²⁶⁶ For weighting factors, see HVAC variable table in section 3.3.

3.3.5. Geothermal Source Heat Pump

DESCRIPTION

This measure characterizes the installation of an ENERGY STAR qualified Geothermal Source Heat Pump (GSHP) either during new construction or at Time of Sale/Replacement of an existing system(s). The baseline is always assumed to be a new baseline Air Source Heat Pump. Savings are calculated due to the GSHP providing heating and cooling more efficiently than a baseline ASHP, plus savings hot water loads utilizing a desuperheater when installed.

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

In order for this characterization to apply, the efficient equipment must be a Geothermal Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed below:

ENERGY STAR Requirements (Effective January 1, 2012)		
Product Type	Cooling EER	Heating COP
Water-to-air		
Closed Loop	17.1	3.6
Open Loop	21.1	4.1
Water-to-Water		
Closed Loop	16.1	3.1
Open Loop	20.1	3.5
DGX	16	3.6

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a commercially rated Air Source Heat Pump meeting the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012.²⁶⁷

Note: The Code of Federal Regulations mandates that manufacturers comply with minimum efficiency standards for certain types of heat pump equipment. Due to the fact that all equipment available for purchase must comply with this regulation, the Code of Federal Regulation shall be taken as the principle authoritative source for specification of baseline efficiency where applicable. Only in instances where equipment types or efficiency values are not specified by the Code of Federal Regulations shall they be sourced from IECC 2012. New Federal Standards affecting heat pumps became effective January 1, 2023.

Code of Federal Regulations: Table 3 to §431.97—Updates to the Minimum Cooling Efficiency Standards for Air Conditioning and Heating Equipment and Table 4 to §431.97—Updates to the Minimum Heating Efficiency Standards for Air-Cooled Air Conditioning and Heating Equipment [Heat Pumps]²⁶⁸

²⁶⁷ The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 * SEER^2) + (1.12 * SEER)$ Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Equivalent EER is also approximated with this formula: $EER = IEER/F$ where F is based on a relationship between EER and IEER in ASHRAE 90.1 2010 Table 6.8.1A (approximately 1.018 for units 65,000 to 240,000 Btu/h and 1.01 for units 240,000 to 760,000 Btu/h).

²⁶⁸ The new compliance standards set by the Code of Federal Regulations for commercial air source heat pumps are more aggressive and have a higher minimum cooling and heating efficiency requirements as compared to IECC 2012. In this instance, federal standards supersede state code conservation requirements, and the baseline equipment is defined as an air source heat pumping meeting the minimum qualifying criteria as detailed in the Code of Federal Regulations.

Equipment type	Cooling capacity	Heating type	Cooling Efficiency level	Heating Efficiency level	Compliance date
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/h	All	SEER2 = 14.3 (SEER = 15) EER2 = 11.9 (EER = 12.3)	HSPF2 = 7.5 (HSPF = 8.8)	1/1/2023
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000Btu/h	All	SEER2 = 13.4 (SEER = 14.0) EER2 = 11.7 (EER = 11.4)	HSPF2 = 6.7 (HSPF = 8.0)	1/1/2023
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.2 EER = 12.0	N/A	1/1/2018
			IEER = 14.1 EER = 11.8		1/1/2023
		All Other Types of Heating	IEER = 12.0 EER = 11.8	COP = 3.3	1/1/2018
			IEER = 13.9 EER = 11.7	COP = 3.4	1/1/2023
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 11.6 EER = 11.4	N/A	1/1/2018
			IEER = 13.5 EER = 11.5		1/1/2023
		All Other Types of Heating	IEER = 11.4 EER = 11.2	COP = 3.2	1/1/2018
			IEER = 13.3 EER = 11.4	COP = 3.3	1/1/2023
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 10.6 EER = 10.5	N/A	1/1/2018
			IEER = 12.5 EER = 10.9		1/1/2023
		All Other Types of Heating	IEER = 10.4 EER = 10.3	COP = 3.2	1/1/2018
			IEER = 12.3 EER = 10.8		1/1/2023

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected equipment measure life for Time of Sale or New Construction is assumed to be 25 years.²⁶⁹

DEEMED MEASURE COST

The actual installed cost of the Geothermal Source Heat Pump should be used (default of \$4,081per ton)²⁷⁰, minus

²⁶⁹ The expected system life of indoor components is assumed to be 25 years as per U.S. Department of Energy (DOE) estimates from the Office of Energy Efficiency & Renewable Energy, Energy Saver Articles on Heat Pump Systems – Geothermal Heat Pumps. 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).

²⁷⁰ Based on data provided on Home Advisor website, providing national average GSHP costs based on actual project quotes from 132 Home Advisor members and contractors. Equipment and material cost of \$2,581 per ton plus an added \$1,500 per ton installation cost (assuming vertical looping).

the assumed installation cost of the baseline equipment (\$1,867 per ton for ASHP).²⁷¹ 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 of an efficient ASHP over the baseline ASHP. For this scenario only, the incremental capital cost for air-cooled units is assumed to be \$467.99 per ton for up to and including CEE Tier 1 class products,²⁷² and \$935.98 per ton for CEE Tier 2 and higher class products.²⁷³

An estimate of additional cost required for a desuperheater is \$1,500.²⁷⁴

LOADSHAPE

Loadshape NREP01:16 - Nonresidential Electric Heat Pump (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\begin{aligned} \Delta kWh &= [Cooling\ savings] + [Heating\ savings] + [DHW\ savings\ if\ displacing\ electric\ DHW] \\ &= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{EE-PL}} \right) + FLF_{Cool} * \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{EE-FL}} \right) \right)}{1000} \right] \\ &+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{HSPF_{Base}} - \frac{1}{(COP_{EE-PL} * 3.412)} \right) + FLF_{Heat} * \left(\frac{1}{HSPF_{Base}} - \frac{1}{(COP_{EE-FL} * 3.412)} \right) \right)}{1000} \right] \\ &+ \left[\frac{ElecDHW * \%DHW * \frac{1}{EF_{elecbase}} * HotWaterUseGallon * \gamma_{Water} * (T_{Out} - T_{In})}{3412} \right] \end{aligned}$$

Where:

- EFLH_{Cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use
- 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

²⁷¹ Based on data provided on Home Advisor website, providing national average ASHP costs based on actual project quotes from 3,523 Home Advisor members and contractors.

²⁷² For specification details see; <https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0>

²⁷³ NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

²⁷⁴ Based on web review, e.g. <https://www.123zeroenergy.com/geothermal-desuperheater.html>.

	= 0.85 if variable speed GSHP ²⁷⁵
	= 0 if single/constant speed GSHP
	= 0.71 if unknown speed type ²⁷⁶
FLF _{Cool}	= Full load cooling mode operation factor
	= 0.15 if variable speed GSHP
	= 1 if single/constant speed GSHP
	= 0.29 if unknown speed type ²⁷⁷
EER _{Base}	= Energy Efficiency Ratio (EER) of the baseline equipment (new ASHP unit); use minimum standard efficiencies as specified in the table in ‘Definition of Baseline Equipment’ section ²⁷⁸
EER _{EE - PL}	= Part Load EER Efficiency of efficient GSHP unit
	= Actual installed with adjustment for pumping energy. ²⁷⁹
	Adjusted EER (closed loop) = 0.0000315*EER ³ - 0.0111*EER ² + 0.959*EER
	Adjusted EER (open loop) = 0.00005*EER ³ - 0.0145*EER ² + 0.93*EER
EER _{EE - FL}	= Full Load EER Efficiency of ENERGY STAR GSHP unit
	= Actual installed with adjustment for pumping energy described above
EFLH _{Heat}	= Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
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 ²⁸⁰
	= 0 if single/constant speed GSHP
	= 0.42 if unknown speed type ²⁸¹
FLF _{Heat}	= Full load heating mode operation factor
	= 0.5 if variable speed GSHP

²⁷⁵ 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.

²⁷⁶ Based on distribution of 2022 IPL program participation data

²⁷⁷ Based on distribution of 2022 IPL program participation data

²⁷⁸ The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Equivalent EER is also approximated with this formula: EER = IEER/F where F is based on a relationship between EER and IEER in ASHRAE 90.1 2010 Table 6.8.1A (approximately 1.018 for units 65,000 to 240,000 Btu/h and 1.01 for units 240,000 to 760,000 Btu/h).

²⁷⁹ The methodology provided is based upon REMRate protocol ‘Auxiliary Electric Energy of Ground Source Heat Pumps’; http://www.resnet.us/standards/Auxiliary_Electric_Energy_of_Ground_Source_Heat_Pumps_Amendment.pdf

²⁸⁰ 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.

²⁸¹ Based on distribution of 2022 IPL program participation data

	= 1 if single/constant speed GSHP
	= 0.58 if unknown speed type ²⁸²
HSPF _{Base}	= Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh); use minimum standard efficiencies as specified in the table in 'Definition of Baseline Equipment' section ²⁸³
COP _{EE - PL}	= Part Load Coefficient of Performance of efficient unit = Actual Installed with adjustment for pumping energy: ²⁸⁴
	Adjusted COP (closed loop) = $0.000416 * COP^3 - 0.041 * COP^2 + 1.0086 * COP$
	Adjusted COP (open loop) = $0.00067 * COP^3 - 0.0531 * COP^2 + 0.976 * COP$
COP _{EE - FL}	= Full Load Coefficient of Performance of efficient unit = Actual Installed with adjustment for pumping energy described above
3.412	= Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).
Elec _{DHW}	= 1 if building has electric DHW = 0 if building has non electric DHW = 0 if one to one replacement of existing Ground Source Heat Pump = 0.478 if unknown ²⁸⁵
%DHW	= Percentage of total DHW load that the GSHP will provide = Actual if known = If unknown and if desuperheater installed, assume 44% ²⁸⁶ = if unknown and if unknown whether desuperheater is installed, assume 23% (e.g. midstream program application) ²⁸⁷ = 0% if no desuperheater installed
EF _{elecbase}	= Energy Factor of baseline or existing electric DHW = Actual. If unknown assume federal standard as defined in 3.2.3 Hot Water Heater measure
HotWaterUse _{Gallon}	= Estimated annual hot water consumption (gallons) = Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:
	1. Consumption per usable storage tank capacity = Capacity * Consumption/cap
	Where:

²⁸² Based on distribution of 2022 IPL program participation data

²⁸³ Federal standards detail heating efficiency in terms of coefficient of performance (COP). In order to convert HSPF to COP, multiply by the constant, 3.412.

²⁸⁴ The methodology provided is based upon REMRate protocol 'Auxiliary Electric Energy of Ground Source Heat Pumps'; http://www.resnet.us/standards/Auxiliary_Electric_Energy_of_Ground_Source_Heat_Pumps_Amendment.pdf

²⁸⁵ Percentage of commercial buildings in Iowa that utilize electric as their primary water heater fuel type, as sourced from NREL ComStock (data accessed on May 16, 2023).

²⁸⁶ Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year ($2/3 * 2/3 = 44\%$). Based on input from Doug Dougherty, Geothermal Exchange Organization.

²⁸⁷ 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.

Capacity = Usable capacity of hot water storage tank (gallons)
 = Actual²⁸⁸

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:²⁸⁹

Building Type ²⁹⁰	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	377
Small Office	511
Small Retail	528
Warehouse	341
Nursing	672
Multifamily	894
Nonresidential Weighted Average	438 ²⁹¹

- Consumption per unit area by building type
 = (Area/1000) * Consumption/1,000 sq.ft.

Where:

Area = Area in sq.ft that is served by DHW boiler
 = Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:²⁹²

²⁸⁸ If the replaced unit is a tankless water heater, the 2nd method provided or an alternative should be used to estimate consumption.

²⁸⁹ Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data for West North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

²⁹⁰ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

²⁹¹ Consumption values weighted for the nonresidential average are sourced from the EFLH weighting tables in the 3.3 HVAC End Use section

²⁹² Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of West North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

Building Type ²⁹³	Consumption/1,000 sq. ft.
Convenience	3,634
Education	5,440
Grocery	1,150
Health	13,663
Large Office	1,205
Large Retail	157
Lodging	18,541
Other Commercial	3,573
Restaurant	26,927
Small Office	931
Small Retail	913
Warehouse	476
Nursing	26,721
Multifamily	13,133
Nonresidential Weighted Average	3,420 ²⁹⁴

γ_{Water} = Specific weight capacity of water (lb/gal)

= 8.33 lbs/gal

c_p = Specific heat of water (Btu/lbm/°F)

T_{out} = Unmixed Outlet Water Temperature

= custom, otherwise assume 140²⁹⁵

T_{in} = Inlet Water Temperature

= custom - otherwise assume 56.5²⁹⁶

²⁹³ According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

²⁹⁴ Consumption values weighted for the nonresidential average are sourced from the EFLH weighting tables in the 3.3 HVAC End Use section

²⁹⁵ Ideally the actual set point of the water heater should be used. If not, 140 degrees is provided as an estimate based on review of building and plumbing codes for IA. The codes limit temperatures at the end use but not at the water heater system, which can be anywhere in the range 120 -201 degrees. Generally speaking, code limits the temperature to fixtures to 120 degrees F and 140 degrees for applications like laundry or dishwashing.

²⁹⁶ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. <http://www.nrel.gov/docs/fy10osti/47246.pdf>; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

For example, for a 5 ton closed loop GSHP with desuperheater unit with 24 Part Load EER, 18 Full Load EER and 4.2 Part Load COP, 3.8 Full Load COP installed in an existing school in Burlington, IA with an electric 0.95 UEF 80 gallon DHW tank:

$$\begin{aligned} \text{Adjusted Part Load EER} &= 0.0000315 * 24^3 - 0.0111 * 24^2 + 0.959 * 24 \\ &= 17.1 \end{aligned}$$

$$\begin{aligned} \text{Adjusted Full Load EER} &= 0.0000315 * 18^3 - 0.0111 * 18^2 + 0.959 * 18 \\ &= 13.8 \end{aligned}$$

$$\begin{aligned} \text{Adjusted Part Load COP} &= 0.000416 * 4.2^3 - 0.041 * 4.2^2 + 1.0086 * 4.2 \\ &= 4.2 \end{aligned}$$

$$\begin{aligned} \text{Adjusted Full Load COP} &= 0.000416 * 3.8^3 - 0.041 * 3.8^2 + 1.0086 * 3.8 \\ &= 3.3 \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (1,073 * 60,000 * ((0.85 * (1/(11.8 - 1/17.1)) + (0.15 * (1/(11.8 - 1/13.8)))) / 1,000 + (968 * 60,000 * ((0.5 * (1/8.2 - 1/(4.2 * 3.412))) + (0.5 * (1/8.2 - 1/(3.3 * 3.412)))) / 1,000 + ((1 * 0.44 * 1/0.95 * (100 * 568) * 8.33 * (140-56.5))/3412) \\ &= 1,556.0 + 3,312.8 + 4290.3 \\ &= 9,159 kWh \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left(\frac{Capacity_{cool} * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{EE-FL}} \right)}{1000} \right) * CF$$

Where:

EERbase = Energy Efficiency Ratio (EER) of the baseline equipment (new ASHP unit); use minimum standard efficiencies as specified in the table in ‘Definition of Baseline Equipment’ section.²⁹⁷

EER_{FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit
= Actual

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ²⁹⁸	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio

²⁹⁷ The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Equivalent EER is also approximated with this formula: EER = IEER/F where F is based on a relationship between EER and IEER in ASHRAE 90.1 2010 Table 6.8.1A (approximately 1.018 for units 65,000 to 240,000 Btu/h and 1.01 for units 240,000 to 760,000 Btu/h).

²⁹⁸ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ²⁹⁸	Model Source
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ²⁹⁹	92.3%	N/A

For example, for a 5 ton closed loop GSHP unit with 18 Full Load EER installed in an existing school in Burlington, IA.:

$$\begin{aligned} \text{Adjusted Full Load EER} &= 0.0000315 * 18^3 - 0.0111 * 18^2 + 0.959 * 18 \\ &= 13.8 \end{aligned}$$

$$\begin{aligned} \Delta kW &= (60,000 * (1/11.8 - 1/13.8) / 1,000) * 0.967 \\ &= 0.7127 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

$$\begin{aligned} \Delta \text{Therm} &= [\text{DHW savings if displacing gas DHW}] \\ &= \frac{Ga_{DHW} * \%DHW * \frac{1}{EF_{GasBase}} * \text{HotWaterUseGallon} * \gamma_{Water} * (T_{Out} - T_{In}) * 1.0}{100,000} \end{aligned}$$

Where:

Ga_{DHW} = 1 if building has gas DHW
 = 0 if building has electric DHW
 = 0 if one to one replacement of existing Ground Source Heat Pump

$EF_{GasBase}$ = Energy factor of baseline of existing natural gas DHW heater
 = Actual. If unknown assume federal standard as defined in 3.2.3 Hot Water Heater measure

100,000 = Converts Btu to Therms
 Other variables as provided above.

PEAK GAS SAVINGS

It is assumed that savings from a desuperheater will occur throughout the year. The Peak Gas Savings is therefore assumed to be:

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

²⁹⁹ For weighting factors, see HVAC variable table in section 3.3.

Where:

Δ Therms = Therm impact calculated above
365.25 = Days per year

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR- HVAC-GSHP-V06-240101

SUNSET DATE: 1/1/2026

3.3.6. Single-Package and Split System Unitary Air Conditioners

DESCRIPTION

This measure promotes the installation of high-efficiency unitary air-, water-, and evaporatively cooled air conditioning equipment, both single-package and split systems. Air conditioning (AC) systems are a major consumer of electricity and systems that exceed baseline efficiencies can save considerable amounts of energy. This measure could apply to the replacing of an existing unit at the end of its useful life or the installation of a new unit in a new or existing building.

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

In order for this characterization to apply, the efficient equipment is assumed to be a high-efficiency air-, water-, or evaporatively cooled air conditioner that exceeds the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-, water-, or evaporatively cooled air conditioner that meets the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.³⁰⁰

DEEMED MEASURE COST

The incremental capital cost for this measure is based upon capacity and efficiency level (defined by CEE specifications),³⁰¹ as outlined in the following table:³⁰²

Capacity	Incremental cost (\$/ton)	
	Up to and including CEE Tier 1 units	CEE Tier 2 and above
< 135,000 Btu/hr	\$63.42	\$126.84
135,000 Btu/hr to > 250,000 Btu/hr	\$63.42	\$126.84
250,000 Btu/hr and greater	\$18.92	\$37.83

LOADSHAPE

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

Algorithm

CALCULATION OF SAVINGS

Note: The Code of Federal Regulations mandates that manufacturers comply with minimum efficiency standards for certain types of heat pump equipment. Due to the fact that all equipment available for purchase must comply with

³⁰⁰ Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

³⁰¹ For specification details see; <https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0>

³⁰² NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

this regulation, the Code of Federal Regulation shall be taken as the authoritative source for specification of baseline efficiency in instances where IECC 2012 requires less aggressive efficiency standards.

ELECTRIC ENERGY SAVINGS

For units with cooling capacities less than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}} \right)}{1000} \right]$$

For units with cooling capacities less than 65 kBtu/hr using the M1 Testing Method:

$$\Delta kWh = \left[\frac{EFLH_{cool} \cdot Capacity_{cool} \cdot \left(\frac{1}{SEER2_{base}} - \frac{1}{SEER2_{ee}} \right)}{1000} \right]$$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}} \right)}{1000} \right]$$

Where:

- Capacity_{cool} = Cooling output capacity of new equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)
= Actual installed
- SEER_{base} = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh); see table below for default values³⁰³
- SEER_{ee} = Seasonal Energy Efficiency Ratio of installed unit (kBtu/kWh)
= Actual installed
- SEER2_{base} = Seasonal Energy Efficiency Ratio 2 of baseline unit (kBtu/kWh); see table below for default values
- SEER2_{ee} = Seasonal Energy Efficiency Ratio 2 of installed unit (kBtu/kWh)
= Actual installed
- IEER_{base} = Integrated Energy Efficiency Ratio of baseline unit (kBtu/kWh); see table below for default values³⁰⁴. Where heating type is unknown (e.g. mid or upstream program), assume “All other types”.
- IEER_{ee} = Integrated Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh)
= Actual installed
- EFLH_{cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use

Code of Federal Regulations: Table 3 to §431.97—Updates to the Minimum Cooling Efficiency Standards for Air Conditioning and Heating Equipment

³⁰³ Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

³⁰⁴ Code of Federal Regulations and International Energy Conservation Code (IECC) 2012

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.6 Single-Package and Split System Unitary Air Conditioners

Equipment type	Cooling capacity	Heating type	Efficiency level	Compliance date
Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.9 IEER = 14.8	1/1/2018 1/1/2023
		All Other Types of Heating	IEER = 12.7 IEER = 14.6	1/1/2018 1/1/2023
Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 12.4 IEER = 14.2	1/1/2018 1/1/2023
		All Other Types of Heating	IEER = 12.2 IEER = 14.0	1/1/2018 1/1/2023
Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled)	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance Heating or No Heating	IEER = 11.6 IEER = 13.2	1/1/2018 1/1/2023
		All Other Types of Heating	IEER = 11.4 IEER = 13.0	1/1/2018 1/1/2023
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System)	<65,000 Btu/h	All	SEER2 = 14.3 (SEER = 15)	1/1/2023
Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package)	<65,000Btu/h	All	SEER2 = 13.4 (SEER = 14)	1/1/2023

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.6 Single-Package and Split System Unitary Air Conditioners

IECC 2012 Specifications:

TABLE C403.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE ^a
				Before 6/1/2011	As of 6/1/2011	
Air conditioners, air cooled	< 65,000 Btu/h ^b	All	Split System	13.0 SEER	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER	13.0 SEER	
Through-the-wall (air cooled)	≤ 30,000 Btu/h ^b	All	Split system	12.0 SEER	12.0 SEER	
			Single Package	12.0 SEER	12.0 SEER	
Small-duct high-velocity (air cooled)	< 65,000 Btu/h ^b	All	Split System	10.0 SEER	10.0 SEER	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 11.4 IEER	
			All other	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER	
			All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.0 IEER
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 10.1 IEER	10.0 EER 10.1 IEER	
			All other	Split System and Single Package	9.8 EER 9.9 IEER	9.8 EER 9.9 IEER
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 9.8 IEER	9.7 EER 9.8 IEER	
			All other	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 9.6 IEER
Air conditioners, water cooled	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360
			All other	Split System and Single Package	11.3 EER 11.5 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.5 EER 12.7 IEER	
			All other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	12.4 EER 12.6 IEER	
			All other	Split System and Single Package	10.8 EER 10.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	12.0 EER 12.4 IEER	
			All other	Split System and Single Package	10.8 EER 10.9 IEER	

(continued)

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.6 Single-Package and Split System Unitary Air Conditioners

**TABLE C403.2.3(1)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE ^a		
				Before 6/1/2011	As of 6/1/2011			
Air conditioners, evaporatively cooled	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240		
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360		
		All other	Split System and Single Package	11.3 EER 11.5 IEER	11.9 EER 12.1 IEER			
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.0 EER 12.2 IEER			
		All other	Split System and Single Package	10.8 EER 11.0 IEER	11.8 EER 12.0 IEER			
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	11.9 EER 12.1 IEER			
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 11.9 IEER			
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.1 IEER	11.7 EER 11.9 IEER			
		All other	Split System and Single Package	10.8 EER 10.9 IEER	11.5 EER 11.7 IEER			
	Condensing units, air cooled	≥ 135,000 Btu/h			10.1 EER 11.4 IEER		10.5 EER 14.0 IEER	AHRI 365
	Condensing units, water cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER		13.5 EER 14.0 IEER	
	Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER		13.5 EER 14.0 IEER	

For SI: 1 British thermal unit per hour = 0.2931 W.

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
- b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

For example, a 5 ton air cooled split system with a SEER2 of 14.3 at an existing small retail building in Burlington would save

$$\begin{aligned} \Delta kWh &= (60,000) * [(1/13.4) - (1/14.3)] / 1000 * 891 \\ &= 251 kWh \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{Capacity_{cool} * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right)}{1000} \right] * CF$$

Where:

EER_{base} = Energy Efficiency Ratio of the baseline equipment; see table above for default values. Where heating type is unknown (e.g. mid or upstream program), assume “All other types”. Since IECC 2012 does not provide EER requirements for air-cooled air conditioners < 65 kBtu/hr, assume the following conversion from SEER to EER: $EER = -0.02 \times SEER^2 + 1.12 \times SEER$

EER_{ee} = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled air conditioners < 65 kBtu/hr, if the actual EER_{ee} is unknown, assume the following conversion from SEER to EER: $EER = -0.02 \times SEER^2 + 1.12 \times SEER$

= Actual installed

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type). If unknown (e.g. mid or upstream program) assume nonresidential average.

Building Type	CF ³⁰⁵	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ³⁰⁶	92.3%	N/A

For example, a 5 ton air cooled split system with a SEER2 of 14.3 (EER unknown) at an existing small retail building in Burlington would save:

$$\begin{aligned}
 \text{EER2base} &= -0.02 \times 13.4^2 + 1.12 \times 13.4 \\
 &= 11.4 \text{ EER2} \\
 \text{EER2ee} &= -0.02 \times 14.3^2 + 1.12 \times 14.3 \\
 &= 11.9 \text{ EER} \\
 \Delta\text{kW} &= (60,000 * [(1/11.4) - (1/11.9)] / 1000 * 1.00 \\
 &= 0.2211 \text{ kW}
 \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE: NR-HVC-SPUA-V06-240101

SUNSET DATE: 1/1/2026

³⁰⁵ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

³⁰⁶ For weighting factors, see HVAC variable table in section 3.3.

3.3.7. Electric Chiller

DESCRIPTION

This measure relates to the installation of a new electric chiller meeting the efficiency standards presented below. This measure could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in an existing building (i.e. time of sale). Only single-chiller applications should be assessed with this methodology. The characterization is not suited for multiple chillers projects or chillers equipped with variable speed drives (VSDs).

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

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements of the 2012 International Energy Conservation Code, Table C403.2.3(7)

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to meet the efficiency requirements of the 2012 International Energy Conservation Code, Table C403.2.3(7).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.³⁰⁷

DEEMED MEASURE COST

The incremental capital cost for this measure is provided below:³⁰⁸

Air cooled, electrically operated (\$/ton)				
Capacity (tons)	< 9.9 EER	9.9 EER and < 10.2 EER	10.2 EER and < 10.52 EER	10.52 EER and greater
< 50	\$160	\$302	\$408	\$479
>= 50 and <100	\$80	\$151	\$204	\$239
>= 100 and <150	\$53	\$101	\$204	\$160
>= 150 and <200	\$40	\$75	\$102	\$120
>= 200	\$20	\$38	\$51	\$60

Water cooled, electrically operated, positive displacement (rotary screw and scroll) (\$/ton)				
Capacity (tons)	> .72 kW/ton	.72 and > .68 kW/ton	.68 and >.64 kW/ton	.64 kW/ton and less
< 50	\$362	\$604	N/A	N/A
>= 50 and <100	\$166	\$287	N/A	N/A

³⁰⁷ California Public Utilities Commission, Workpaper and Disposition Archive, Updated April 11, 2022, SWHC020-02 Air-Cooled Chiller-Final .docx .

³⁰⁸ NEEP incremental cost update for Version 7 of the Mid-Atlantic TRM. Original data and analysis sourced from Itron. Measure and baseline costs were calculated using hedonic models and data from Itron, 2010 –2012 W0017 Ex Ante Measure Cost Study, conducted for the California Public Utility Commission in 2014 and adjusted for inflation. See supporting document “NEEP Chiller Incremental Cost_Recommendations_050917_IA TRM V8 update.xlsx”

Water cooled, electrically operated, positive displacement (rotary screw and scroll) (\$/ton)				
Capacity (tons)	> .72 kW/ton	.72 and > .68 kW/ton	.68 and >.64 kW/ton	.64 kW/ton and less
>= 100 and <150	N/A	N/A	N/A	N/A
>= 150 and <200	N/A	N/A	\$60	\$121
>= 200	N/A	N/A	N/A	\$15

Water cooled, electrically operated, positive displacement (reciprocating) (\$/ton)			
Capacity (tons)	> .60 kW/ton	.60 and > .58 kW/ton	.58 kW/ton and less
< 100	\$103	\$163	\$284
>= 100 and <150	\$68	\$109	\$189
>= 150 and <200	\$51	\$81	\$142
>= 200 and <300	N/A	N/A	\$36
>= 300	N/A	N/A	\$15

LOADSHAPE

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = TONS * ((IPLV_{base}) - (IPLV_{ee})) * EFLH$$

Where:

- TONS = chiller nominal cooling output capacity in tons (note: 1 ton = 12,000 Btu/hr)
= Actual installed
- IPLV_{base} = efficiency of baseline equipment expressed as Integrated Part Load Value(kW/ton). Chiller units are dependent on chiller type. See ‘Chiller Units, Conversion Values’ and ‘Baseline Efficiency Values by Chiller Type’ and Capacity in the Reference Tables section.
- IPLV_{ee}³⁰⁹ = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)³¹⁰
= Actual installed
- EFLH = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use.

For example, a 100 ton air-cooled electrically operated chiller in an existing warehouse with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) in unknown location would save:

$$\begin{aligned} \Delta kWh &= 100 * ((0.96) - (0.86)) * 864 \\ &= 8,640 kWh \end{aligned}$$

³⁰⁹ Integrated Part Load Value is a seasonal average efficiency rating calculated in accordance with ARI Standard 550/590. It may be calculated using any measure of efficiency (EER, kW/ton, COP), but for consistency with IECC 2012, it is expressed in terms of IPLV here.

³¹⁰ Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRnetl.org. <http://www.ahrnet.org/>

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = TONS * ((PE_{base}) - (PE_{ee})) * CF$$

Where:

- PE_{base} = Peak efficiency of baseline equipment expressed as Full Load (kW/ton)
= See “FULL LOAD” values from ‘Baseline Efficiency Values by Chiller Type and Capacity’ in Reference Tables section.
- PE_{ee} = Peak efficiency of high efficiency equipment expressed as Full Load (kW/ton)
= Actual installed
- CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ³¹¹	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ³¹²	92.3%	N/A

For example, a 100 ton air-cooled electrically operated chiller in an existing warehouse with a full load efficiency of 12 EER (1 kW/ton) with baseline full load efficiency of 9.5 EER (1.26 kW/ton) in unknown location would save:

$$\Delta kW = 100 * ((1.26) - (1.0)) * 0.779$$

$$= 20.25 \text{ kW}$$

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

³¹¹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

³¹² For weighting factors, see HVAC variable table in section 3.3.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES

Chillers Ratings - Chillers are rated with different units depending on equipment type as shown below.

Equipment Type	Unit
Air cooled, electrically operated	EER
Water cooled, electrically operated, positive displacement (reciprocating)	kW/ton
Water cooled, electrically operated, positive displacement (rotary screw and scroll)	kW/ton

In order to convert chiller equipment ratings to IPLV, the following relationships are provided:

kW/ton = 12 / EER

kW/ton = 12 / (COP x 3.412)

COP = EER / 3.412

COP = 12 / (kW/ton) / 3.412

EER = 12 / kW/ton

EER = COP x 3.412

Baseline Efficiency Values by Chiller Type and Capacity³¹³

Note: Efficiency requirements depend on the path (Path A or Path B) that the building owner has chosen to meet compliance requirements. For air cooled and absorption chillers, Path A should be assumed. For water cooled chillers, the building owner should be consulted and the relevant path used for calculations. When unknown, Path A should be used.

³¹³ International Energy Conservation Code (IECC)2012

**TABLE C403.2.3(7)
MINIMUM EFFICIENCY REQUIREMENTS:
WATER CHILLING PACKAGES***

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010		AS OF 1/1/2010 ^b				TEST PROCEDURE ^c	
			FULL LOAD	IPLV	PATH A		PATH B			
					FULL LOAD	IPLV	FULL LOAD	IPLV		
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.416	≥ 9.562	≥ 12.500	NA	NA	AHRI 550/590	
	≥ 150 tons	EER			≥ 9.562	≥ 12.750	NA	NA		
Air cooled without condenser, electrical operated	All capacities	EER	≥ 10.586	≥ 11.782	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements					
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	≤ 0.837	≤ 0.696	Reciprocating units shall comply with water cooled positive displacement efficiency requirements					
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton			≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600		
	≥ 75 tons and < 150 tons	kW/ton	≤ 0.790	≤ 0.676	≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586		
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.717	≤ 0.627	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540		
	≥ 300 tons	kW/ton	≤ 0.639	≤ 0.571	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490		
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.703	≤ 0.669						
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450		
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400		
	≥ 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400		
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NR	≥ 0.600	NR	NA	NA		AHRI 560
Water cooled, absorption single effect	All capacities	COP	≥ 0.700	NR	≥ 0.700	NR	NA	NA		
Absorption double effect, indirect fired	All capacities	COP	≥ 1.000	≥ 1.050	≥ 1.000	≥ 1.050	NA	NA		
Absorption double effect, direct fired	All capacities	COP	≥ 1.000	≥ 1.000	≥ 1.000	≥ 1.000	NA	NA		

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

NA = Not applicable, not to be used for compliance; NR = No requirement.

- a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.
- b. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.
- c. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

MEASURE CODE: NR-HVC-CHIL-V03-240101

SUNSET DATE: 1/1/2028

3.3.8. Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

DESCRIPTION

A PTAC is a packaged terminal air conditioner that cools and sometimes provides heat through an electric resistance heater (heat strip). A PTHP is a packaged terminal heat pump. A PTHP uses its compressor year round to heat or cool. In warm weather, it efficiently captures heat from inside your building and pumps it outside for cooling. In cool weather, it captures heat from outdoor air and pumps it into your home, adding heat from electric heat strips as necessary to provide heat.

This measure characterizes:

- a) Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.
- b) Early Replacement: the early removal of an existing PTAC or PTHP from service, prior to its natural end of life, and replacement with a new efficient PTAC or PTHP unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life. The measure is only valid for non-fuel switching installations – for example replacing a cooling only PTAC with a PTHP can currently not use the TRM.

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 PTACs or PTHPs that exceed baseline efficiencies.

DEFINITION OF BASELINE EQUIPMENT

Time of Sale: the baseline conditions is provided in the Federal Baseline reference table provided below.

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 8 years.³¹⁴

Remaining life of existing equipment is assumed to be 3 years.³¹⁵

DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this equipment is estimated to be \$84/ton.³¹⁶

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unknown assume \$1,047 per ton.³¹⁷

The assumed deferred cost (after 3 years) of replacing existing equipment with new baseline unit is assumed to be

³¹⁴ Based on 2015 DOE Technical Support Document, as recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018

³¹⁵ Standard assumption of one third of effective useful life.

³¹⁶ DEER 2008. This assumes that baseline shift from IECC 2006 to IECC 2012 carries the same incremental costs. Values should be verified during evaluation

³¹⁷ Based on DCEO – IL PHA Efficient Living Program data.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.8 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

\$1,039 per ton.³¹⁸ This cost should be discounted to present value using the utilities’ discount rate.

LOADSHAPE

Loadshape NREP01:16 - Nonresidential Electric Heat Pump (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

ENERGY SAVINGS

Time of Sale:

$$\text{PTAC } \Delta\text{kWh}^{319} = \text{Annual kWh Savings}_{\text{cool}}$$

$$\text{PTHP } \Delta\text{kWh} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\Delta\text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{cool}} * \left(\frac{1}{\text{EER}_{\text{base}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1000} \right]$$

$$\Delta\text{kWh Savings}_{\text{heat}} = \left[\frac{\text{EFLH}_{\text{heat}} * \text{Capacity}_{\text{heat}} * \left(\frac{1}{\text{COP}_{\text{base}}} - \frac{1}{\text{COP}_{\text{ee}}} \right)}{3412} \right]$$

Early Replacement:

$$\Delta\text{kWh for remaining life of existing unit (1st 3 years) = Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\Delta\text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{cool}} * \left(\frac{1}{\text{EER}_{\text{exist}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1000} \right]$$

$$\Delta\text{kWh Savings}_{\text{heat}} = \left[\frac{\text{EFLH}_{\text{heat}} * \text{Capacity}_{\text{heat}} * \left(\frac{1}{\text{COP}_{\text{exist}}} - \frac{1}{\text{COP}_{\text{ee}}} \right)}{3412} \right]$$

$$\Delta\text{kWh for remaining measure life (next 5 years) = Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\Delta\text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{cool}} * \left(\frac{1}{\text{EER}_{\text{base}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1000} \right]$$

$$\Delta\text{kWh Savings}_{\text{heat}} = \left[\frac{\text{EFLH}_{\text{heat}} * \text{Capacity}_{\text{heat}} * \left(\frac{1}{\text{COP}_{\text{base}}} - \frac{1}{\text{COP}_{\text{ee}}} \right)}{3412} \right]$$

³¹⁸Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.

³¹⁹ There are no heating efficiency improvements for PTACs since although some do provide heating, it is always through electric resistance and therefore the COPbase and COPee would be 1.0.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.8 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

Where:

- EFLH_{cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use.
- Capacity_{cool} = Cooling output capacity of Air Source Heat Pump (Btu/hr)
= Actual (where 1 ton = 12,000Btu/hr)
- EER_{base} = Energy Efficiency Ratio of the baseline equipment; see the table below for values.
- EER_{ee} = Energy Efficiency Ratio of the energy efficient equipment.
= Actual installed
- EER_{exist} = Energy Efficiency Ratio of the existing equipment
= Actual. If unknown assume 9.9 EER for PTAC and 9.7 EER for PTHP³²⁰
- EFLH_{heat} = heating mode equivalent full load hours are provided in section 3.3 HVAC End Use.
- Capacity_{Heat} = Heating output capacity of Air Source Heat Pump (Btu/hr)
= Actual (where 1 ton = 12,000Btu/hr)
- COP_{base} = coefficient of performance of the baseline equipment; see table below for values.
- COP_{ee} = coefficient of performance of the energy efficient equipment.
= Actual installed
- COP_{exist} = coefficient of performance of the existing equipment
= Actual. If unknown assume 2.9 COP for PTHPs³²¹
- 3,412 = kBtu per kWh.

Federal Equipment Standards, 10 CFR 431.97(c): Minimum Efficiency Requirements for PTAC and PTHP

Equipment Type	Category	Cooling Capacity	Minimum Efficiency
PTAC (Cooling mode)	Standard Size	< 7,000Btu/h	11.9 EER
		≥ 7,000 and ≤ 15,000 Btu/h	14.0 – (0.300 x Cap/1000) EER
		> 15,000 Btu/h	9.5 EER
	Non-Standard Size*	< 7,000Btu/h	9.4 EER
		≥ 7,000 and ≤ 15,000 Btu/h	10.9 – (0.213 x Cap/1000) EER
		> 15,000 Btu/h	7.7 EER
PTHP (Cooling mode)	Standard Size	< 7,000Btu/h	11.9 EER
		≥ 7,000 and ≤ 15,000 Btu/h	14.0 – (0.300 x Cap/1000) EER
		> 15,000 Btu/h	9.5 EER
	Non-Standard Size*	< 7,000Btu/h	9.3 EER
		≥ 7,000 and ≤ 15,000 Btu/h	10.8 – (0.213 x Cap/1000) EER
		> 15,000 Btu/h	7.6 EER
Standard Size	< 7,000Btu/h	3.3 COP	
	≥ 7,000 and ≤ 15,000 Btu/h	3.7 – (0.052 x Cap/1000) COP	

³²⁰ Estimated using the IECC building energy code up effective between IECC 2003 and IECC 2012. Assuming a 1 ton unit; PTAC: EER = 12.5 – (0.213 * 12,000/1,000) = 9.9 and PTHP: EER = 12.3 – (0.213 * 12,000/1,000) = 9.7.

³²¹ Estimated using the IECC building energy code up effective between IECC 2003 and IECC 2012. Assuming a 1 ton unit; COP = 3.2 – (0.026 * 12,000/1,000) = 2.9

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.8 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

Equipment Type	Category	Cooling Capacity	Minimum Efficiency
PTHP (Heating mode)	Non-Standard Size*	> 15,000 Btu/h	2.9 COP
		< 7,000Btu/h	2.7 COP
		≥ 7,000 and ≤ 15,000 Btu/h	2.9 – (0.026 x Cap/1000) COP
		> 15,000 Btu/h	2.5 COP

“Cap” = The rated cooling capacity of the project in Btu/hr. If the units capacity is less than 7000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit’s capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculations.

*Non-standard size applies only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.

Time of Sale (assuming standard size baseline):

For example, a 1 ton PTAC with an efficient EER of 12 at an existing hotel in Burlington saves:

$$= [(12,000) * [(1/10.4) - (1/12)] / 1000 * 1,464$$

$$= 225 \text{ kWh}$$

Early Replacement (assuming replacement baseline for deferred replacement in 3 years):

For example, a 1 ton PTHP with an efficient EER of 12, COP of 3.0 at an existing restaurant in unknown location replaces a PTAC unit (with electric resistance heat) with unknown efficiency.

ΔkWh for remaining life of existing unit (1st 3 years)

$$= (12,000 * (1/8.1 - 1/12) * 1,173) / 1,000 + (12,000/3,412 * (1/1.0 - 1/3.0) * 1,249)$$

$$= 565 + 2,929$$

$$= 3,494 \text{ kWh}$$

ΔkWh for remaining measure life (next 5 years)

$$= (12,000 * (1/8.3 - 1/12) * 1,173) / 1,000 + (12,000/3,412 * (1/1.0 - 1/3.0) * 1,249)$$

$$= 523 + 2,929$$

$$= 3,452 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale:

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right)}{1000} \right] * CF$$

Early Replacement:

ΔkW for remaining life of existing unit (1st 3 years):

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{EER_{exist}} - \frac{1}{EER_{ee}} \right)}{1000} \right] * CF$$

ΔkWh for remaining measure life (next 5 years):

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right)}{1000} \right] * C$$

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.8 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

Where:

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ³²²	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ³²³	92.3%	N/A

Time of Sale:

For example, a 1 ton PTAC with an efficient EER of 12 at an existing hotel in Burlington saves:

$$\begin{aligned} \Delta kW &= (12,000 * (1/10.4 - 1/12) / 1,000 * 0.974 \\ &= 0.15 \text{ kW} \end{aligned}$$

Early Replacement (assuming replacement baseline for deferred replacement in 3 years):

For example, a 1 ton PTHP with an efficient EER of 12, COP of 3.0 at an existing restaurant in unknown location replaces a PTAC unit (with electric resistance heat) with unknown efficiency.

ΔkW for remaining life of existing unit (1st 3 years):

$$\begin{aligned} \Delta kW &= 12,000 * (1/8.1 - 1/12) / 1,000 * 0.996 \\ &= 0.48 \text{ kW} \end{aligned}$$

ΔkW for remaining measure life (next 5 years):

$$\begin{aligned} \Delta kW &= 12,000 * (1/8.3 - 1/12) / 1,000 * 0.996 \\ &= 0.43 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

³²² This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

³²³ For weighting factors, see HVAC variable table in section 3.3.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.8 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

N/A

MEASURE CODE: NR-HVC-PTAC-V03-220101

SUNSET DATE: 1/1/2025

3.3.9. Guest Room Energy Management (PTAC)

DESCRIPTION

This measure applied to the installation of a temperature setback and lighting control system for individual guest rooms. The savings are achieved based on Guest Room Energy Management’s (GREM’s) ability to automatically adjust lighting levels and the guest room’s set temperatures and control the packaged terminal air conditioner (PTAC) unit when the room is not occupied.

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

Guest room temperature set point must be controlled by automatic occupancy detectors or keycard that indicates the occupancy status of the room. During unoccupied periods the system sets heating and cooling to a minimum, and turns off lighting when the key card is removed. Once the guest returns and inserts the key card, the guest has full control of the room systems. This measure bases savings on improved HVAC controls and reduced lighting loads. The incentive is per guestroom controlled, rather than per sensor, for multi-room suites. Replacement or upgrades of existing occupancy-based controls are not eligible for an incentive.

DEFINITION OF BASELINE EQUIPMENT

Guest room energy management thermostats replace manual lighting controls and heating/cooling temperature set-point and fan On/Off/Auto thermostat controls for the PTAC.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for GREM is 15 years.³²⁴

DEEMED MEASURE COST

\$260/unit

The incremental measure cost documented for this measure is \$260 per room HVAC controller, which is the cost difference between a non-programmable thermostat and a GREM.³²⁵

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape NREH07 – Nonresidential Electric Heat – Lodging

Loadshape NRECH07 – Nonresidential Cooling – Lodging

Loadshape NRGH07 – Nonresidential Gas Heating – Lodging

Algorithm

CALCULATION OF SAVINGS

Below are the annual kWh savings per installed energy management system for different climate zones. The savings

³²⁴ DEER 2008 value for energy management systems

³²⁵ This value was extracted from Smart Ideas projects in PY1 and PY2.

are achieved based on GREM’s ability to automatically adjust the guest room’s set temperatures and control the HVAC unit to maintain set temperatures for various occupancy modes. If the GREM is capable of controlling lighting, additional savings result. The basis of savings is the 2013 California Building Energy Standards, which used EnergyPro 5 simulation.³²⁶ For PTACs that use gas for heating, separate gas savings are outlined.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Rooms * ([Heating\ savings] + [Cooling\ savings] + [Lighting\ savings])$$

Where:

Rooms = Number of rooms with a GREM system installed.

Other variables as listed in the table below:

Climate Zone	Heating savings [kWh/room/year]	Cooling savings [kWh/room/year]	Lighting savings [kWh/room/year]
Zone 5 (Burlington)	111.3	24.6	62.0
Zone 6 (Mason City)	151.5	17.8	62.0
Average / Unknown	135.8	22.2	62.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = Rooms * \frac{Cooling\ savings}{EFLH_{Cool}} * CF$$

Where:

EFLH_{Cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use

CF = Summer System Peak Coincidence Factor for Cooling,
= 97.4% (for Lodging)

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

For PTACs with gas heating:

$$\Delta Therms = Rooms * [Gas\ Savings]$$

Where:

Rooms = Number of rooms with a GREM system installed.

Gas Savings factor as listed in the table below:

Climate Zone	Gas Savings ³²⁷ [therms/room/year]
Zone 5 (Burlington)	4.7

³²⁶ Results for California were adjusted to be Iowa-specific using a comparison of heating and cooling degree day differences. See the supporting workbook titled “Hotel Energy Management.xlsx” for additional detail.

³²⁷ Savings include the assumption that the thermal efficiency of the heating unit is 80%, per IECC2012 code.

Climate Zone	Gas Savings ³²⁷ [therms/room/year]
Zone 6 (Mason City)	6.5
Average / Unknown	5.8

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

= 1.3205% for Lodging³²⁸

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-GREM-V03-220101

SUNSET DATE: 1/1/2026

³²⁸ Calculated as the percentage of total savings in the maximum savings day, from model.

3.3.10. Boiler Tune-up

DESCRIPTION

This measure is for a nonresidential boiler that provides space heating. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. 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 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.
- Verify boiler delta T is within system design limits.

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 NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Loadshape NRGB01:16 – Nonresidential Gas Heat and Hot Water (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{Capacity * EFLH * \left(\frac{Effbefore + Ei}{Effbefore} - 1 \right)}{100,000}$$

Where:

- Capacity = Gas Boiler input size (Btu/hr)
= Actual
- EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
- Effbefore = Combustion Efficiency of the boiler before the tune-up
= Actual
- Ei = Combustion Efficiency Improvement of the boiler tune-up measure³²⁹
= Actual
- 100,000 = Converts Btu to therms

For example, for a 200 kBtu boiler in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta therms &= (200,000 * 1358 * (((0.82 + 0.018)/ 0.82) - 1)) /100,000 \\ &= 60.0 therms \end{aligned}$$

³²⁹ 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.

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ³³⁰	Model Source
Convenience	1.6310%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4240%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1745%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ³³¹	1.4623%	N/A

For example, for a 200 kBtu boiler in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta PeakTherms &= 60.0 * 0.0167180 \\ &= 1.00031 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

While there is 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: NR-HVC-BLRT-V03-240101

SUNSET DATE: 1/1/2026

³³⁰ Calculated as the percentage of total savings in the maximum saving day, from models.

³³¹ For weighting factors see HVAC variable table in section 3.3.

3.3.11. Furnace Tune-Up

DESCRIPTION

This measure is for a tune-up to a natural gas furnace that provides space heating in a nonresidential application. 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 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.
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits.
- Check and adjust gas input.
- Check high limit and other safety controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline for a clean and check tune-up is a furnace assumed not to have had a tune-up in the past 2 years.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life of a clean and check tune-up is 2 years.³³²

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune-up.

LOADSHAPE

³³² Based on VEIC professional judgment.

Loadshape NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Loadshape NREH01:16 – Nonresidential Electric Heating (by Building Type)

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta Therms * F_e * 29.3$$

Where:

- $\Delta Therms$ = as calculated below
- F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
= 3.14%³³³
- 29.3 = kWh per therm

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:

- EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
- Capacity = Nominal Heating Input Capacity Furnace Size (Btu/hr)
= Actual
- Effbefore = Combustion Efficiency of the furnace before the tune-up
= Actual
- E_i = Combustion Efficiency Improvement of the furnace tune-up measure³³⁴
= Actual
- 100,000 = Conversion of Btu to Therms

For example, for a 200 kBtu furnace in an existing small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta therms &= (200,000 * 1358 * (((0.82 + 0.018) / 0.82) - 1)) / 100,000 \\ &= 60.0 therms \end{aligned}$$

³³³ 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.

³³⁴ 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.

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ³³⁵	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ³³⁶	1.4658%	N/A

For example, for a 200 kBtu furnace in a small office in unknown location that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta PeakTherms &= 60.0 * 0.0167180 \\ &= 1.0031 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

While there is 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: NR-HVC-FTUN-V03-200101

SUNSET DATE: 1/1/2026

³³⁵ Calculated as the percentage of total savings in the maximum saving day, from models.

³³⁶ For weighting factors, see HVAC variable table in section 3.3.

3.3.12. Small Commercial Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new Programmable or Advanced Thermostat for reduced heating and cooling energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses as defined by programs,³³⁷ as they have smaller HVAC systems that are similar to residential HVAC systems and may be controlled by a simple manual adjustment thermostat. Mid- to large-sized businesses will typically have a building automation system or some other form of automated HVAC controls. Therefore, use of this measure characterization is limited to select building types (such as convenience stores, small retail, low rise office, restaurants, religious facilities). This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for programmable thermostats installed in multi-zone systems.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change the temperature setpoint.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a thermostat is assumed to be 8 years.³³⁸

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown, the capital cost for this measure is assumed to be \$181.³³⁹

LOADSHAPE

NREC17 – Non-Residential Cooling – Small Programmable Thermostat

NREPO1:16 – Non-Residential Electric Heat Pump (by Building Type)

NRGH01:16 – Nonresidential Gas Heating (by Building Type)

³³⁷ The square footage of the small office prototype building modeled in is 7,500 sf.

³³⁸ 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.

³³⁹ Nicor Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013.

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:

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

If central cooling exists, the electric energy saved in annual cooling due to the thermostat is:

$$\Delta kWh_{cooling} = \frac{Sqft * Savings Factor_{cool}}{EfficiencyRating(exist)_{cool}}$$

Where:

Sqft = square footage of building controlled by thermostat

EfficiencyRating(exist)_{cool} = efficiency rating of existing cooling equipment EER (btu hr/W)

If unknown assume code minimum

Savings Factor_{cool} = cooling savings factor

= 0.53 kBtu/sf-yr³⁴⁰

If the building is heated with electric heat (heat pump), the electric energy saved in annual heating due to the thermostat is:

$$\Delta kWh_{heating} = \frac{Sqft * Savings Factor_{heat}}{3.412 * EfficiencyRating(exist)_{electric heat}}$$

Where:

Savings Factor_{heat} = 0.85 kBtu/sf-yr³⁴¹

3.412 = Conversion from kBtu to kWh

EfficiencyRating(exist)_{electric heat} = efficiency rating of existing heating system

= Actual. If unknown assume code minimum. *Note: heat pumps will have an efficiency greater than 100%*

Other factors as defined above.

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to furnace fans operating fewer hours:

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

³⁴⁰ Cooling Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the small office prototype building (7,500 sf) and converted to kBtu.

³⁴¹ Heating Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the prototype building (7,500 sf) and converted to kBtu.

Fe = Percentage of heating energy consumed by fans, assume 3.14%³⁴²

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

0.0³⁴³

NATURAL GAS ENERGY SAVINGS

If building uses a gas heating system, the savings resulting from the thermostat is calculated with the following formula:

$$\Delta Therms = \frac{Sqft * Savings Factor_{heat}}{100 * EfficiencyRating(exist)_{heat}}$$

Where:

Sqft = square footage of building controlled by thermostat

EfficiencyRating(exist)_{heat} = efficiency rating of existing heating equipment (AFUE)
If unknown assume code minimum

Savings Factor_{heat} = 0.85 kBtu/sf-yr³⁴⁴

PEAK GAS SAVINGS

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

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ³⁴⁵	Model Source
Convenience	0.016482	eQuest
Education	0.011480	OpenStudio
Grocery	0.013083	OpenStudio
Health	0.010179	OpenStudio
Hospital	0.015543	OpenStudio
Industrial	0.014296	eQuest
Lodging	0.013205	OpenStudio
Multifamily	0.012268	OpenStudio
Office - Large	0.013082	OpenStudio
Office - Small	0.016718	OpenStudio
Religious	0.011964	eQuest
Restaurant	0.015262	OpenStudio
Retail - Large	0.013281	eQuest

³⁴² F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

³⁴³ modeling work used to simulate savings for this measure showed no summer peak demand savings.

³⁴⁴ Heating Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the prototype building (7,500 sf) and converted to kBtu.

³⁴⁵ Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF ³⁴⁵	Model Source
Retail - Small	0.014055	OpenStudio
Warehouse	0.015677	eQuest
Nonresidential Average ³⁴⁶	0.014658	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-PROG-V05-220101

SUNSET DATE: 1/1/2026

³⁴⁶ For weighting factors, see HVAC variable table in section 3.3.

3.3.13. Variable Frequency Drives for HVAC Pumps and Cooling Tower Fans

DESCRIPTION

This measure applies to variable frequency drives (VFDs) / [variable speed drives \(VSDs\)](#) installed on HVAC chilled water and hot water distribution pumps (centrifugal pumps only) and cooling tower fans. There is a separate measure for HVAC supply and return fans. The VFD/VSD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is not applicable for:

- Cooling towers, chilled or hot water pumps with any process load.
- VFD/VSD installation in existing cooling towers with 2-speed motors. (current code requires 2-speed motors for cooling towers with motors greater than 7.5 HP)
- VFD/VSD installation in new cooling towers with motors greater than 7.5 HP

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD/VSD is applied to a pump motor 1-100 HP that [is not currently controlled by](#) a VFD/VSD. The hydronic system that the VFD/VSD is applied to must have a variable or reduced load. Installation is to include the necessary control points and parameters (example: differential pressure, differential temperature, return water temperature) as determined by a qualified engineer. The savings are based on the application of VFDs/VSDs applied to a range of baseline systems, including no control, inlet or outlet guide vanes, throttling valves, and three-way valves with bypass.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD/VSD. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves, or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VFDs/VSDs that are required by IECC 2012 as adopted by the State of Iowa are not eligible to claim savings.³⁴⁷

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.³⁴⁸

DEEMED MEASURE COST

Customer-provided costs will be used when available. Default incremental VFD/VSD costs are listed below for 1 to 100 HP motors.³⁴⁹

³⁴⁷ IECC provisions for existing buildings are as follows: “Additions, alterations, renovations or repairs to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portion(s) of the existing building or building system to comply with this Code”.

³⁴⁸ (PG&E, 2019) "SWHC018-02 - Variable Speed Drive For HVAC Fan Controls, Commercial.pdf", pg. 8

³⁴⁹ Incremental costs are sourced from the “NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013” and adjusted to account for inflation and regional labor cost differences between the Mid-Atlantic region and the state of Iowa. The Bureau of Labor Statistics, Occupational Employment Statistics, State Occupational Employment and Wage Estimates from May 2018 were leveraged in order to identify prevailing wage differences between the location of the original study and the state of Iowa.

HP	Cost
1-9 HP	\$2,538
10-19 HP	\$3,640
20-29 HP	\$4,989
30-39 HP	\$5,855
40-49 HP	\$6,721
50-59 HP	\$7,683
60-69 HP	\$8,801
70-79 HP	\$9,527
80-89 HP	\$10,253
90-100 HP	\$11,162

LOADSHAPE

Loadshape NRE07 – VFD - Boiler feedwater pumps

Loadshape NRE08 – VFD - Chilled water pumps

Loadshape NRE09 – VFD - Boiler circulation pumps

Loadshape NRE18 - VFD - Cooling Tower Fans

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{BHP}{EFFi} * Hours * ESF$$

Where:

BHP = System Brake Horsepower

= (Nominal motor HP * Motor load factor)

Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined.³⁵⁰ Custom load factor may be applied if known.

EFFi = Motor efficiency, installed.

= Actual

Hours = Default hours are provided for HVAC applications which vary by building type.³⁵¹ When available, actual hours should be used.

The type of hours to apply depends on the VFD/VSD application, according to the table below.

Application	Hours Type
Hot Water Pump	Heating
Chilled Water Pump	Cooling

³⁵⁰ Del Balso, Ryan J. “Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications”, University of Colorado, Department of Civil, Environmental and Architectural Engineering, 2013.

³⁵¹ Based on models developed in OpenStudio. Building types denoted with an asterisk indicate values were referenced from the ComEd TRM June 1, 2010 page 139.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.13 Variable Frequency Drives for HVAC Pumps and Cooling Tower Fans

Application	Hours Type
Cooling Tower Fan	Cooling

Building Type	Heating Run Hours	Cooling Run Hours
Convenience*	3628	2690
Education	6367	2796
Grocery	6499	2725
Health	8720	4770
Hospital	8289	8760
Industrial*	3977	3080
Lodging	5500	7909
Multifamily	5382	5084
Office - Large	5316	4596
Office - Small	1952	2138
Religious*	4763	2223
Restaurant	3027	2719
Retail – Large*	4218	2405
Retail - Small	3029	2266
Warehouse*	4100	1788
Nonresidential Average	3659	2182

ESF = Energy savings factor varies by VFD/VSD application. Units are kW/HP.

Application	ESF ³⁵²
Hot Water Centrifugal Pump	0.187
Chilled Water Centrifugal Pump	0.094
Cooling Tower Fan	0.382

For example, a VFD operating 2386 hours annually driving a 50-horsepower motor with 95% efficiency and a load factor of 70% on a chilled water pump would save:

$$\begin{aligned} \Delta kWh &= 50/0.95 * 0.70 * 2386 * 0.094 \\ &= 8,263 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{BHP}{EFF_i} * DSF$$

Where:

DSF = Demand Savings Factor varies by VFD/VSD application.³⁵³ Units are kW/HP. Values listed below are based on typical peak load for the listed application.

Application	DSF
Hot Water Centrifugal Pump	0
Chilled Water Centrifugal Pump	0
Cooling Tower Fan	0.32

³⁵² Based on OpenStudio Large Office model, finding difference in energy use for each VSD application. See ‘VSD Savings Factor Calc.xls’.

³⁵³ Based on OpenStudio Large Office model, finding difference in maximum demand during peak period for each VSD application. See ‘VSD Savings Factor Calc.xls’

For example, a VFD operating 2386 hours annually driving a 50-horsepower motor with 95% efficiency and a load factor of 70% on a cooling tower fan would save:

$$\begin{aligned}\Delta kW &= 50/0.95 * 0.7 * 0.32 \\ &= 11.79kW\end{aligned}$$

NATURAL GAS ENERGY SAVINGS

There are no expected fossil fuel impacts for this measure.³⁵⁴

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-VFHP-V05-240101

SUNSET DATE: 1/1/2028

³⁵⁴ Consider updating measure to include heating and cooling savings in future revisions.

3.3.14. Variable Frequency Drives for HVAC Supply and Return Fans

DESCRIPTION

This measure applies to variable frequency drives (VFDs) installed on HVAC supply fans and return fans. There is a separate measure for HVAC Pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is applicable to the following program types: TOS, RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to an HVAC fan motor 1-100 HP that does not have a VFD. The air distribution system must have a variable or reduced load, and installation is to include the necessary control point as determined by a qualified engineer (e.g., differential pressure, temperature, or volume). Savings are based on the application of VFDs to a range of baseline system conditions, including no control, inlet guide vanes, outlet guide vanes, relief dampers, and throttling valves.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD or other methods of control. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves, or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VFDs that are required by IECC 2012 as adopted by the State of Iowa are not eligible to claim savings.³⁵⁵

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for a VFD in HVAC application is 15 years.³⁵⁶

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs are listed below for up to 100 hp motors.³⁵⁷

HP	Cost
1-9 HP	\$2,177
10-19 HP	\$3,123
20-29 HP	\$4,280
30-39 HP	\$5,023
40-49 HP	\$5,766
50-59 HP	\$6,591
60-69 HP	\$7,550

³⁵⁵ IECC provisions for existing buildings are as follows: “Additions, alterations, renovations or repairs to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portion(s) of the existing building or building system to comply with this Code”.

³⁵⁶ “NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013.”

³⁵⁷ Incremental costs are sourced from the “NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013” and adjusted to account for regional labor cost differences between the Mid-Atlantic region and the state of Iowa. The Bureau of Labor Statistics, Occupational Employment Statistics, State Occupational Employment and Wage Estimates from May 2018 were leveraged in order to identify prevailing wage differences between the location of the original study and the state of Iowa.

HP	Cost
70-79 HP	\$8,173
80-89 HP	\$8,796
90-100 HP	\$9,576

LOADSHAPE

Loadshape NRE04 – VFD - Supply fans
 Loadshape NRE05 – VFD - Return fans
 Loadshape NRE06 – VFD - Exhaust fans

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS³⁵⁸

$$kWh_{Base} = \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * RHRS_{Base} * \sum_{0\%}^{100\%} (\%FF * PLR_{Base})$$

$$kWh_{Retrofit} = \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * RHRS_{base} * \sum_{0\%}^{100\%} (\%FF * PLR_{Retrofit})$$

$$\Delta kWh_{fan} = kWh_{Base} - kWh_{Retrofit}$$

$$\Delta kWh_{total} = \Delta kWh_{fan} * (1 + IE_{energy})$$

Where:

- kWh_{Base} = Baseline annual energy consumption (kWh/yr)
- $kWh_{Retrofit}$ = Retrofit annual energy consumption (kWh/yr)
- ΔkWh_{fan} = Fan-only annual energy savings
- ΔkWh_{total} = Total project annual energy savings
- 0.746 = Conversion factor for HP to kWh
- HP = Nominal horsepower of controlled motor
- LF = Load Factor; Motor Load at Fan Design CFM (Default = 65%)³⁵⁹
- η_{motor} = Installed nominal/nameplate motor efficiency
= Actual
- $RHRS_{Base}$ = Annual operating hours for fan motor based on building type

³⁵⁸ Methodology developed and tested in Del Balso, Ryan Joseph. “Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications”. A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013.

³⁵⁹ Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). “Improving Motor and Drive System Performance; A Sourcebook for Industry”. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Golden, CO: National Renewable Energy Laboratory.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.14 Variable Frequency Drives for HVAC Supply and Return Fans

= Default hours are provided for HVAC applications which vary by building type.³⁶⁰
When available, actual hours should be used.

Building Type	Fan Run Hours
Convenience*	4630
Education	3544
Grocery	8743
Health	3478
Hospital	4570
Industrial*	2850
Lodging	3909
Multifamily	8760
Office - Large	2662
Office - Small	7667
Religious*	2412
Restaurant	7300
Retail - Large*	4065
Retail - Small	7410
Warehouse*	2920
Nonresidential Average ³⁶¹	4978

%FF = Percentage of run-time spent within a given flow fraction range:³⁶²

Flow Fraction (% of design cfm)	Percent of Time at Flow Fraction
0% to 10%	0.0%
10% to 20%	1.0%
20% to 30%	5.5%
30% to 39%	15.5%
40% to 49%	22.0%
50% to 59%	25.0%
60% to 69%	19.0%
70% to 79%	8.5%
80% to 89%	3.0%
90% to 100%	0.5%

PLR_{Base} = Part load ratio for a given flow fraction range based on the baseline flow control type (see table below)

PLR_{Retrofit} = Part load ratio for a given flow fraction range based on the retrofit flow control type (see table below)

Control Type	Part Load Ratio for each Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
No Control or Bypass Damper	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

³⁶⁰ Based on outputs from OpenStudio modeling. Building types noted by an asterisk rely on values originally derived from eQuest modeling. In those instances, the fan hours are based on lighting hours by building type. For Fan based HVAC, fans generally operate full speed during building occupancy whether full speed is needed or not. The time VFDs will save energy is during building occupancy hours which corresponds most closely to lighting hours of use.

³⁶¹ For weighting factors, see HVAC variable table in section 3.3.

³⁶² Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.14 Variable Frequency Drives for HVAC Supply and Return Fans

Control Type	Part Load Ratio for each Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Discharge Dampers	0.46	0.55	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, BI & Airfoil Fans	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.56	0.60	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, BI & Airfoil Fans	0.53	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Inlet Vane Dampers	0.38	0.40	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Outlet Damper, FC Fans	0.22	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	0.17	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane, FC Fans	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
VFD with duct static pressure controls	0.09	0.10	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01
VFD with low/no duct static pressure	0.05	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.00

Provided below are the resultant values based upon the defaults provided above:

Control Type	$\sum_{0\%}^{100\%} (\%FF \times PLR_{Base})$
No Control or Bypass Damper	1.00
Discharge Dampers	0.80
Outlet Damper, BI & Airfoil Fans	0.78
Inlet Damper Box	0.69
Inlet Guide Vane, BI & Airfoil Fans	0.63
Inlet Vane Dampers	0.53
Outlet Damper, FC Fans	0.53
Eddy Current Drives	0.49
Inlet Guide Vane, FC Fans	0.39
VFD with duct static pressure controls	0.30
VFD with low/no duct static pressure	0.27

IE_{energy} = HVAC interactive effects factor for energy (default = 15.7%)³⁶³

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$kW_{Base} = \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * PLR_{Base,FFpeak}$$

$$kW_{Retrofit} = \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * PLR_{Retrofit,FFpeak}$$

$$\Delta kW_{fan} = kW_{Base} - kW_{Retrofit}$$

$$\Delta kW_{total} = \Delta kW_{fan} * (1 + IE_{demand})$$

Where:

kW_{Base} = Baseline summer coincident peak demand (kW)

³⁶³ Del Balso, Ryan Joseph. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications". A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.14 Variable Frequency Drives for HVAC Supply and Return Fans

kW_{Retrofit}	= Retrofit summer coincident peak demand (kW)
ΔkW_{fan}	= Fan-only summer coincident peak demand impact
ΔkW_{total}	= Total project summer coincident peak demand impact
$PLR_{\text{Base,FFpeak}}$	= The part load ratio for the average flow fraction between the peak daytime hours during the weekday peak time period based on the baseline flow control type (default average flow fraction during peak period = 90%)
$PLR_{\text{Retrofit,FFpeak}}$	= The part load ratio for the average flow fraction between the peak daytime hours during the weekday peak time period based on the retrofit flow control type (default average flow fraction during peak period = 90%)
IE_{demand}	= HVAC interactive effects factor for summer coincident peak demand (default = 15.7%)

NATURAL GAS ENERGY SAVINGS

There are no expected fossil fuel impacts for this measure.³⁶⁴

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-VFDF-V04-230101

SUNSET DATE: 1/1/2027

³⁶⁴ Consider updating measure to include heating and cooling savings in future revisions.

3.3.15. Duct Insulation

DESCRIPTION

Energy and demand saving are realized through reductions in the building cooling and heating loads by improving thermal resistance of ductwork in unconditioned areas. This measure was developed to be applicable to the following program types: RF.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is ductwork in unconditioned areas with improved thermal resistance.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing ductwork in unconditioned areas.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.³⁶⁵

DEEMED MEASURE COST

Actual project costs should be used since material and labor costs can vary greatly due to factors such as physical access and material costs (e.g., replacing ductwork versus adding insulation to existing).

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

NREP01:16 – Nonresidential Electric Heat Pump (by Building Type)

NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

Savings should only be claimed for ductwork that exists on the exterior of the building or in uninsulated spaces.

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

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

³⁶⁵ Consistent with duct insulation measure life specified in the MidAmerican Energy Company Joint Assessment, February 2013.

- $R_{existing}$ = Duct heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
= Actual, must be non-zero.
- R_{new} = Duct heat loss coefficient with improved insulation [(hr-°F-ft²)/Btu]
= Actual
- Area = Area of the duct surface exposed to the unconditioned space that has been insulated [ft²].
- $EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use
- $\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 60°F duct supply air temperature.³⁶⁶

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ³⁶⁷	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	20.4
Zone 6 (Mason City)	75.2	15.2
Average / Unknown	78.6	18.6

- 1,000 = Conversion from Btu to kBtu
- $\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * EFLH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

Where:

- $EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 4.4, HVAC end use
- $\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 115°F duct supply temperature.³⁶⁸

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ³⁶⁹	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	75.4

³⁶⁶ 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.

³⁶⁷ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

³⁶⁸ 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.

³⁶⁹ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

Climate Zone (City based upon)	OA _{AVG,heating} [°F] ³⁶⁹	ΔT _{AVG,heating} [°F]
Zone 6 (Mason City)	30.1	84.9
Average / Unknown	35.9	79.1

3,142 = Conversion from Btu to kWh.

η_{heating} = Efficiency of heating system

= Actual. *Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%*

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in unknown location with 10.5 SEER central AC, and 1.92COP heat pump system, and the duct R-value with new insulation is 10.0:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{cooling} + \Delta kWh_{heating} \\ &= ((1/3.5 - 1/10.0) * 100 * 780 * 18.6 / (1,000 * 10.5)) + ((1/3.5 - 1/10.0) * 100 * 1,372 * 79.1 / (3,412 * 1.92)) \\ &= 22.2 + 266.2 \\ &= 288.4 \text{ kWh} \end{aligned}$$

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.

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%³⁷⁰

29.3 = Conversion from therms to kWh

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in unknown location with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

$$\begin{aligned} \Delta kWh &= 24.9 * 0.0314 * 29.3 \\ &= 22.9 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

EFLH_{cooling} = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use

³⁷⁰ Fe is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% Fe. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ³⁷¹	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ³⁷²	92.3%	N/A

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in unknown location with 10.5 SEER central cooling, and the duct R-value with new insulation is 10.0:

$$\begin{aligned} \Delta kW &= 22.2 / 780 * 1.00 \\ &= 0.0280 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

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_{cooling} = Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use
- ΔT_{AVG,heating} = Average temperature difference [°F] during heating season (see above)
- 100,000 = Conversion from BTUs to Therms
- η_{heat} = Efficiency of heating system

³⁷¹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.

³⁷² For weighting factors, see HVAC variable table in section 3.3.

= Actual

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in an existing small retail building in unknown location with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

$$\begin{aligned} \Delta\text{Therms} &= ((1/3.5 - 1/8.0) * 100 * 1,372 * 79.1 / (100,000 * 0.70)) \\ &= 24.9 \text{ therms} \end{aligned}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ³⁷³	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ³⁷⁴	1.4658%	N/A

For example, 100 ft² of duct surface with a pre-insulation R-value of 3.5 is insulated in a small retail building in unknown location with a gas furnace with system efficiency of 70%, and the duct R-value with new insulation is 10.0:

$$\begin{aligned} \Delta\text{PeakTherms} &= 24.9 * 0.0140550 \\ &= 0.3500 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

³⁷³ Calculated as the percentage of total savings in the maximum saving day, from models.

³⁷⁴ For weighting factors, see HVAC variable table in section 3.3.

N/A

MEASURE CODE: NR-HVC-DUCT-V03-220101

SUNSET DATE: 1/1/2026

3.3.16. Duct Repair and Sealing

DESCRIPTION

Air leaks in ductwork passing through exterior spaces 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 by qualified/certified HVAC professionals³⁷⁵. Where this occurs, an algorithm is provided to estimate the site specific savings. Where test in/test out has not occurred, a conservative deemed assumption is provided.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be assessed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

DEFINITION OF BASELINE EQUIPMENT

The existing duct leakage to exterior, unconditioned spaces should be determined through approved and appropriate test methods using a blower door and/or duct blasting. The baseline condition of the ductwork upon first inspection significantly affects the opportunity for cost-effective energy savings through air-sealing.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.³⁷⁶

DEEMED MEASURE COST

The actual labor and material cost for this measure should be used in screening.

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

NREPO1:16 – Nonresidential Electric Heat Pump (by Building Type)

NRGH01:16 – Nonresidential Gas Heating (by Building Type)

³⁷⁵ In order for leakage rates to be considered accurate, performance testing must be carried out by a professional with a high level of experience in the C&I building sector.

³⁷⁶ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Test In / Test Out Approach

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

Where:

$$\Delta kWh_{cooling} = \text{If central cooling, reduction in annual cooling requirement due to air sealing}$$

$$= \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{cooling} * \Delta T_{AVG,cooling} * 0.018 * LM}{(1000 * \eta_{cooling})}$$

CFM_{Pre} = Average duct leakage to exterior at normal operating conditions as estimated by professional testing before air sealing
 = Actual³⁷⁷

CFM_{Post} = Average duct leakage to exterior at normal operating conditions as estimated by professional testing after air sealing
 = Actual

60 = Converts Cubic Feet per Minute to Cubic Feet per Hour

EFLH_{cooling} = Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use

ΔT_{AVG,cooling} = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 60°F duct supply air temperature:³⁷⁸

Climate Zone (City based upon)	OA _{AVG,cooling} [°F] ³⁷⁹	ΔT _{AVG,cooling} [°F]
Zone 5 (Burlington)	80.4	20.4
Zone 6 (Mason City)	75.2	15.2
Average / Unknown	78.6	18.6

0.018 = Specific Heat Capacity of Air (Btu/ft³*°F)

LM = Latent multiplier to account for latent cooling demand
 = dependent on location:³⁸⁰

Climate Zone (City based upon)	LM
Zone 5 (Burlington)	5.0

³⁷⁷ This savings estimate assumes that any conditioned air leaked through exterior ducting will need to subsequently be made up with outside air. CFM calculations should be performed and provided by a qualified HVAC professional.

³⁷⁸ 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.

³⁷⁹ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

³⁸⁰ The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads, again assuming outside makeup air. 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.

Climate Zone (City based upon)	LM
Zone 6 (Mason City)	5.9
Average/ unknown	5.2

1000 = Converts Btu to kWh

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kWh/kWh)
= Actual

$\Delta kWh_{heating}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \frac{(CFM_{pre} - CFM_{post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(\eta_{heating} * 3,412)}$$

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 3.3, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 115°F duct supply temperature:³⁸¹

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ³⁸²	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	75.4
Zone 6 (Mason City)	30.1	84.9
Average / Unknown	35.9	79.1

3,142 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system
= Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%

For example, an existing small retail building (2,000 Sq) Ft in unknown location with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{cooling} + \Delta kWh_{heating} \\ &= [((40 - 25) * 60 * 780 * 18.6 * 0.018 * 5.2) / (1000 * 10.5)] + \\ &\quad [((40 - 25) * 60 * 13721608 * 79.1 * 0.018) / (1.92 * 3,412)] \\ &= 116 + 268 \\ &= 384 \text{ kWh} \end{aligned}$$

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * L_{Duct}$$

Where:

³⁸¹ 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.

³⁸² National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

SavingsPerUnit = Annual savings per linear foot installed airsealing material, dependent on heating / cooling equipment³⁸³

Note: savings factors are additive. For example, a building with both heating and cooling provided by heat pumps would save (1.64+3.27) = 4.91 kWh/ft

End Use	HVAC System	SavingsPerUnit (kWh/ft)
Cooling DX	Air Conditioning	1.64
Space Heat	Electric Resistance/Furnace	5.00
Heat Pump - Cooling	Heat Pump	1.64
Heat Pump - Heating	Heat Pump	3.27

L_{Duct} = Linear footage of airsealing material applied to exterior ductwork seams, closures or joints.
 = Actual

Additional Fan savings

$\Delta kWh_{heating}$ = 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%³⁸⁴

29.3 = kWh per therm

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$\Delta kWh = 17.9 * 0.0314 * 29.3 = 16.5 \text{ kWh}$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

EFLH_{cooling} = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ³⁸⁵	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio

³⁸³ The values in the table represent estimates that are half those provided by Cadmus for the Joint Assessment, based on building simulations performed. The conservative 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.

³⁸⁴ F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Furnace Fan Analysis.xlsx" for reference.

³⁸⁵ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ³⁸⁵	Model Source
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ³⁸⁶	92.3%	N/A

For example, an existing small retail building (2,000 Sq) Ft in unknown location with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned} \Delta kW &= 116 / 780 * 1.00 \\ &= 0.15 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

$$\Delta Therms = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(\eta_{heating} * 100,000)}$$

Where:

$$100,000 = \text{Conversion from BTUs to Therms}$$

Other factors as defined above.

For example, an existing restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned} \Delta Therms &= ((40 - 25) * 60 * 1040 * 75.4 * 0.018) / (0.70 * 100,000) \\ &= 17.9 \text{ therms} \end{aligned}$$

Conservative Deemed Approach

$$\Delta Therms = SavingsPerUnit * L_{Duct}$$

Where:

$$SavingsPerUnit = \text{Annual savings per linear foot, dependent on heating / cooling equipment:}^{387}$$

³⁸⁶ For weighting factors, see HVAC variable table in section 3.3.

³⁸⁷ The values in the table represent estimates of savings from a 3% improvement in total usage. The values are half those provided by Cadmus for the Joint Assessment, based on building simulations performed. The conservative 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.

End Use	HVAC System	SavingsPerUnit (Therms/ft)
Space Heat Boiler	Gas Boiler*	0.26
Space Heat Furnace	Gas Furnace	0.26

*Note: in instances where boilers supply heat to terminal units or VAV boxes that are already inside conditioned space, savings should not be claimed, as not conditioned air is not passing through exterior ductwork.

L_{Duct} = Linear footage of exterior ductwork sealed

= Actual

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ³⁸⁸	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ³⁸⁹	1.4658%	N/A

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned} \Delta PeakTherms &= 17.9 * 0.0152620 \\ &= 0.2732 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

³⁸⁸ Calculated as the percentage of total savings in the maximum saving day, from models.

³⁸⁹ For weighting factors, see HVAC variable table in section 3.3.

MEASURE CODE: NR-HVC-DCTS-V03-220101

SUNSET DATE: 1/1/2026

3.3.17. Chiller Pipe Insulation

DESCRIPTION

Energy and demand saving are realized through reductions in the building cooling loads by insulating supply and return chiller piping that passes through unconditioned areas.

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 chiller piping in unconditioned areas that has been insulated.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing chiller piping in unconditioned areas.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.³⁹⁰

DEEMED MEASURE COST

The incremental measure cost for insulation is the full cost of adding insulation to the pipe. Actual installation costs should be used for the measure cost. For planning purposes, the following costs can be used to estimate the full cost of materials and labor, based on RS Means pricing.³⁹¹ The following table summarizes the estimated costs for this measure per foot of insulation added and include installation costs:

	Insulation Thickness	
	1 Inch	2 Inches
Pipe- RS Means #	220719.10.5170	220719.10.5530
Jacket- RS Means #	220719.10.0156	220719.10.0320
Jacket Type	PVC	Aluminum
Insulation Cost per foot	\$9.40	\$13.90
Jacket Cost per foot	\$4.57	\$7.30
Total Cost per foot	\$13.97	\$21.20

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

Savings should only be claimed for chiller piping that exists on the exterior of the building or in uninsulated spaces.

ELECTRIC ENERGY SAVINGS

The electric energy saved in annual cooling due to the added insulation is:

³⁹⁰ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

³⁹¹ RS Means 2008. Mechanical Cost Data, pages 106 to 119

$$\Delta kWh_{cooling} = \frac{(L_{SP} + L_{OC}) * EFLH_{cooling} * (HG_{Base} - HG_{Eff})}{(1,000 * \eta_{cooling})}$$

Where:

L_{SP} = Length of straight pipe to be insulated (linear foot)
 = actual installed (linear foot)

L_{OC} = Total equivalent length of the other components (valves and tees) of pipe to be insulated
 = See following table “Equivalent Length of Other Components – Elbows and Tees” for equivalent lengths. The total equivalent length is equal to the sum of equivalent lengths for each component; e.g., five 1” straight tee components has a total equivalent length of (5 x .38ft) = 1.9ft.

Equivalent Length of Other Components – Elbows and Tees (L_{oc})³⁹²

Nominal Pipe Diameter	Equivalent Length of Other Components (ft)	
	90 Degree Elbow	Straight Tee
1”	0.30	0.38
2”	0.66	0.63

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 3.3, HVAC end use

$HG_{Base/Eff}$ = Average heat gain factor [BTU/hr/ft] for the baseline and efficient cases, respectively.
 = Based on insulation thickness as shown in the following table:³⁹³

Insulation Thickness [in.]	Average Heat Gain [BTU/hr/ft]
Bare	47.100
0.5	14.413
1	9.063
1.5	6.973
2	5.798
2.5	5.038
3	4.450
3.5	4.068
4	3.768
4.5	3.475
5	3.288
5.5	3.130
6	2.990
6.5	2.875
7	2.770
7.5	2.680
8	2.600
8.5	2.523
9	2.455
9.5	2.398

³⁹² Process Heat Transfer: Principles and Applications, Robert W. Serth, 2014 (Appendix D: Equivalent Lengths of Pipe Fittings)

³⁹³ Based on simulation results from 3E Plus v4.1. Values are the average of 850F MF Blanket, Type IV, C553-11 and 450F MF BLANKET, Type II, C553-11 insulation types and assume working temperatures of 68F ambient and 40F process. See reference workbook titled “Chiller Pipe Simulation Factors.xlsx” for additional details.

Insulation Thickness [in.]	Average Heat Gain [BTU/hr/ft]
10	2.340

- 1,000 = Conversion from Btu to kBtu
- $\eta_{cooling}$ = Energy efficiency ratio (EER) of cooling system (kBtu/kWh)
- = Actual. If not directly specified, EER may be calculated from other commonly listed efficiency ratings (kW/ton or COP):
- EER = 12 / kW/ton
- EER = COP x 3.412

For example, 3” thick insulation is installed on 100 feet of 2” diameter, bare straight pipe with 5 straight tee components in an existing industrial building in unknown location with a 12.0 EER cooling system:

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

$$= ((100 + 3.2) * 1,063 * (47.100 - 4.450)) / (1,000 * 12)$$

$$= 389.9 kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- EFLH_{cooling} = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use
- CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ³⁹⁴	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ³⁹⁵	92.3%	N/A

³⁹⁴ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.

³⁹⁵ For weighting factors, see HVAC variable table in section 3.3.

For example, 3” thick insulation is installed on 100 feet of 2” diameter, bare straight pipe with 5 straight tee components in an industrial building in unknown location with a 12.0 EER cooling system:

$$\begin{aligned} \Delta kW &= 389.9/1,063 * 0.446 \\ &= 0.1636 \text{ kW} \end{aligned}$$

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: NR-HVC-CPIN-V03-200101

SUNSET DATE: 1/1/2022*

* 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.

3.3.18. Hydronic Heating Pipe Insulation

DESCRIPTION

This measure provides rebates for installation of $\geq 1''$ or $\geq 2''$ fiberglass, foam, calcium silicate or other types of insulation with similar insulating properties to existing bare pipe on straight piping as well as other pipe components such as elbows, tees, valves, and flanges for all Nonresidential installations.

Savings estimates are provided for the both exposed indoor or above ground outdoor piping distributing fluid in the following system types (natural gas fired systems only):

- Hydronic heating systems (with or without outdoor reset controls), including:
 - boiler systems that do not circulate water around a central loop and operate upon demand from a thermostat (“non-recirculation”)
 - systems that recirculate during heating season only (“Recirculation – heating season only”)
 - systems recirculating year round (“Recirculation – year round”)
- Low and high-pressure steam systems
 - non-recirculation
 - recirculation - heating season only
 - recirculation - year round

Process piping can also use the algorithms provided but requires custom entry of hours.

Minimum qualifying nominal pipe diameter is 1". Indoor piping must have at least 1" of insulation and outdoor piping must have at least 2" of insulation and include an all-weather protective jacket. New advanced insulating materials may be thinner and savings can be calculated with 3E Plus.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is installing pipe wrap insulation to a length of pipe. Indoor piping must have at least 1" of insulation (or equivalent R-value) and outdoor piping must have at least 2" of insulation (or equivalent R-value) and include an all-weather protective jacket. Minimum qualifying pipe diameter is 1". Insulation must be continuous and contiguous over fittings that directly connect to straight pipe, including elbows and tees.³⁹⁶

DEFINITION OF BASELINE EQUIPMENT

The base case for savings estimates is a bare pipe. Pipes are required by new construction code to be insulated but are still commonly found uninsulated in older commercial buildings.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.³⁹⁷

DEEMED MEASURE COST

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means³⁹⁸ pricing reference materials may be used.³⁹⁹ The following table summarizes the estimated costs for this measure per foot

³⁹⁶ ASHRAE Handbook—Fundamentals, 23.14; Hart, G., “Saving energy by insulating pipe components on steam and hot water distribution systems”, ASHRAE Journal, October 2011

³⁹⁷ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

³⁹⁸ RS Means 2008. Mechanical Cost Data, pages 106 to 119

³⁹⁹ RS Means 2010: “for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting”

of insulation added and include installation costs:

	Insulation Thickness	
	1 Inch (Indoor)	2 Inches (Outdoor)
Pipe- RS Means #	220719.10.5170	220719.10.5530
Jacket- RS Means #	220719.30.0156	220719.40.0320
Jacket Type	PVC	Aluminum
Insulation Cost per foot	\$11.26	\$18.07
Jacket Cost per foot	\$5.94	\$6.93
Total Cost per foot	\$17.20	\$25.00

LOADSHAPE

Loadshape NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Loadshape NRGB01:16 – Nonresidential Gas Heat and Hot Water (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta T_{therms} = \frac{(L_{SP} + L_{OC}) * EFLH_{heating} * (Q_{Base} - Q_{Eff}) * TRF}{(100,000 * \eta_{heat})}$$

Where:

L_{SP} = Length of straight pipe to be insulated (linear foot)
 = actual installed (linear foot)

L_{OC} = Total equivalent length of the other components (valves and tees) of pipe to be insulated
 = See following table “Equivalent Length of Other Components – Elbows and Tees” for equivalent lengths. The total equivalent length is equal to the sum of equivalent lengths for each component; e.g., five 1” straight tee components has a total equivalent length of (5 x .38ft) = 1.9ft.

Equivalent Length of Other Components – Elbows and Tees (L_{oc})⁴⁰⁰

Nominal Pipe Diameter	Equivalent Length of Other Components (ft)	
	90 Degree Elbow	Straight Tee
1”	0.30	0.38
2”	0.66	0.63

⁴⁰⁰ Process Heat Transfer: Principles and Applications, Robert W. Serth, 2014 (Appendix D: Equivalent Lengths of Pipe Fittings)

$EFLH_{heating}$ = Equivalent Full Load Hours for heating [hr] are provided in Section 3.3, HVAC end use

$Q_{Base} - Q_{Eff}$ = Difference in heat loss rate due to the added insulation [BTU/hr/ft]
 = Based on system type and location of the piping as shown in the following table:⁴⁰¹

Pipe Location	System Type	Qbase – Qeff (Btu/hr/ft)
Indoor	Hot Water Space Heating - Without Outdoor Reset	90
	Hot Water Space Heating- With Outdoor Reset, Heating Season Only	61
	Hot Water Space Heating - With Outdoor Reset, Year-Round	45
	Low Pressure Steam	192
	High Pressure Steam	362
Outdoor	Hot Water Space Heating - Without Outdoor Reset	439
	Hot Water Space Heating- With Outdoor Reset, Heating Season Only	347
	Hot Water Space Heating - With Outdoor Reset, Year-Round	293
	Low Pressure Steam	678
	High Pressure Steam	1049

100,000 = Conversion from Btu to Therms

η_{heat} = Efficiency of heating system
 = Actual. If unknown, assume the following:
 = 84% if boiler installed since January 2021. If boiler is older or date is unknown assume 82% for a hot water boiler or 80% for a steam boiler⁴⁰²

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δ therms/ft tables below ⁴⁰³
 = See table below for base TRF values by pipe location

May vary seasonally such as: $TRF[summer] * \text{summer hours} + TRF[winter] * \text{winter hours}$, where TRF values reflecting summer and winter conditions are apportioned by the hours for those conditions. TRF may also be adjusted by building specific balance temperature and operating hours above and below that balance temperature.⁴⁰⁴

Pipe Location	Assumed Regain	TRF, Thermal Regain Factor
Outdoor	0%	1.0
Indoor, heated space	85%	0.15
Indoor, semi- heated, (unconditioned space, with	30%	0.70

⁴⁰¹ The heat loss estimates (Q_{base} and Q_{eff}) were developed using the 3E Plus v4.0 software program, a heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association). The energy savings analysis is based on adding 1-inch (indoor) or 2-inch (outdoor) thick insulation around bare pipe. See reference workbook titled “Hydronic Heating Pipe Insulation.xlsx” for additional details and assumptions.

⁴⁰² Code of Federal Regulations for gas-fired hot water and steam boilers < 300,000 Btu/h and manufactured after September 1, 2012 and before January 15, 2021 (10 CFR 430.32(e)(2)). Effective January 15, 2021 the new federal compliance standard for boilers increases to an AFUE of 84%; however, because this is a retrofit measure, these standards are not applicable to the efficiency of the existing boiler.

⁴⁰³ Thermal regain for *residential* pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012 and Andrews, John, Better Duct Systems for Home Heating and Cooling, U.S. Department of Energy, 2001. Recognizing the differences between residential and commercial heating systems, the factors have been adjusted based on professional judgment. This factor would benefit from additional study and evaluation.

⁴⁰⁴ Thermal Regain Factor_4-30-14.docx

Pipe Location	Assumed Regain	TRF, Thermal Regain Factor
heat transfer to conditioned space. E.g.: boiler room, ceiling plenum, basement, crawlspace, wall)		
Indoor, unheated, (no heat transfer to conditioned space)	0%	1.0
Location not specified	85%	0.15
Custom	Custom	1 – assumed regain

For example, 1” thick insulation is installed on 100 feet of 1” diameter, bare straight pipe with 5 straight tee components distributing fluid in a low-pressure steam system and located in an indoor space heated with a steam boiler, in an industrial building in unknown location:

$$\Delta\text{Therms} = ((100 + 1.9) * 1,183 * 192 * 0.15) / (100,000 * 0.80)$$

$$= 43.4 \text{ therms}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴⁰⁵	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁴⁰⁶	1.4658%	N/A

⁴⁰⁵ Calculated as the percentage of total savings in the maximum saving day, from models.

⁴⁰⁶ For weighting factors, see HVAC variable table in section 3.3.

For example, 1” thick insulation is installed on 100 feet of 1” diameter, bare straight pipe with 5 straight tee components distributing fluid in a low-pressure steam system and located in an indoor space heated with a steam boiler, in an industrial building in unknown location:

$$\begin{aligned}\Delta\text{Therms} &= 43.4 * 0.014296 \\ &= 0.6204 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-HPIN-V04-240101

SUNSET DATE: 1/1/2028

3.3.19. Shut Off Damper for Space Heating Boilers or Furnaces

DESCRIPTION

This measure is for Nonresidential atmospheric boilers or furnaces providing space heating without a shut off damper. When appliances are on standby mode warm room air is drawn through the stack via the draft hood or dilution air inlet at a rate proportional to the stack height, diameter and outdoor temperature. More air is drawn through the vent immediately after the appliance shuts off and the flue is still hot. Installation of a new shut off damper can prevent heat from being drawn up the warm vent and reducing the amount of air that passes through the furnace or boiler heat exchanger. This reduction in air can slightly increase overall operating efficiency by reducing the time needed to achieve steady-state operating conditions.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the space heating boiler or furnace must have a new electrically or thermally activated shut off damper installed on either the exhaust flue or combustion air intake. Barometric dampers do not qualify. The damper actuation shall be interlocked with the firing controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline boiler or furnace incorporates no shut off damper on the combustion air intake or flue exhaust.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the shut off damper is 15 years,⁴⁰⁷ or for the remaining lifetime of the heating equipment, whichever is less.

DEEMED MEASURE COST

Given the variability in cost associated with differences in system specifications and design, as well as choice of measure technology, actual installed costs should be used as available or based on program-specific qualification requirements. When unavailable a deemed measure cost of \$1,500 shall be assumed.⁴⁰⁸

LOADSHAPE

Loadshape NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

⁴⁰⁷ State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009, Table 1-2. Recommended Measure Life by WISEerts Group Description, pg. 1-4.

⁴⁰⁸ CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = N_{gi} * SF * EFLH / 100$$

Where:

N_{gi} = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

= 1%⁴⁰⁹

Note: The savings factor assumes the boiler or furnace is located in an unconditioned space. The savings factor can be higher for those units located within conditioned space.

EFLH = Default Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use. When available, actual hours should be used.

100 = convert kBtu to therms

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴¹⁰	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio

⁴⁰⁹ Based on internet review of savings potential;

“Up to 4%”: Use of Automatic Vent Dampers for New and Existing Boilers and Furnaces, Energy Innovators Initiative Technical Fact Sheet, Office of Energy Efficiency, Canada, 2002

“Up to 1%”: Page 9, The Carbon Trust, “Steam and high temperature hot water boilers”

http://www.carbontrust.com/media/13332/ctv052_steam_and_high_temperature_hot_water_boilers.pdf,

“1 - 2%”: Page 2, Sustainable Energy Authority of Ireland “Steam Systems Technical Guide”, see reference file “SEAI Technical Guide – Steam Systems.”

⁴¹⁰ Calculated as the percentage of total savings in the maximum saving day, from models.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.3.19 Shut Off Damper for Space Heating Boilers or Furnaces

Building Type	GCF ⁴¹⁰	Model Source
Warehouse	1.5677%	eQuest
Nonresidential Average ⁴¹¹	1.4658%	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

A deemed, one-time Operations and Maintenance cost of \$150 shall be included in cost-effectiveness calculations and occur in year 10 of the measure life to account for controller replacement.⁴¹²

MEASURE CODE: NR-HVC-SODP-V02-200101

SUNSET DATE: 1/1/2024*

* 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.

⁴¹¹ For weighting factors, see HVAC variable table in section 3.3.

⁴¹² CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

3.3.20. Room Air Conditioner (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 4.0 Volume 3: Nonresidential Measures; Final: August 2, 2019; Effective January 1, 2020 in which the measure was last active.

3.3.21. Room Air Conditioner Recycling

DESCRIPTION

This measure describes the savings resulting from running a drop-off service taking existing commercial, 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

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.⁴¹³

DEEMED MEASURE COST

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

LOADSHAPE

Loadshapes NREC01-NREC16 dependent on building type.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\begin{aligned} \Delta kWh &= kWh_{exist} - (\%replaced * kWh_{newbase}) \\ &= \frac{Hours * BtuH}{\frac{EER_{exist}}{1.01} * 1000} - (\%replaced * \frac{Hours * BtuH}{CEER_{NewBase} * 1000}) \end{aligned}$$

Where:

Hours = Full Load Hours of room air conditioning unit⁴¹⁴

⁴¹³ One third of assumed measure life for Room AC, which is assumed to be 10.5 years, based on 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)

⁴¹⁴ Equivalent Full load hours for room AC is likely to be significantly lower than for central AC. In the absence of any empirical evidence for commercial room AC use in Iowa, the same relationship as applied in the Residential measure is applied; The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008:

Building Type	Zone 5	Zone 6	Average / Unknown
	(Burlington)	(Mason City)	
Convenience	458	350	419
Education	328	221	290
Grocery	612	460	538
Health	362	278	330
Hospital	571	423	519
Industrial	367	265	330
Lodging	466	336	420
Multifamily	466	336	420
Office - Large	380	301	354
Office - Small	339	244	304
Religious	344	247	320
Restaurant	411	296	365
Retail - Large	375	267	334
Retail - Small	365	261	322
Warehouse	296	215	268
Nonresidential Average	337	241	303

BtuH = Average size of rebated unit. Use actual if available - if not, assume 8500.⁴¹⁵

EERexist = Efficiency of recycled unit
 = Actual if recorded - If not, assume 9.4.⁴¹⁶

%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% ⁴¹⁷

CEERNewbase = Efficiency of baseline unit

http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf to FLH for Central Cooling for the same location (provided by AHRI: [see reference file "RoomAC_Calculator"](#)) is 31%. This ratio has been applied to the EFLH assumptions from Section 3.3 (modeling).

⁴¹⁵ Based on maximum capacity average from the RLW Report; "Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008."

⁴¹⁶ 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.

⁴¹⁷ In the absence of empirical evidence for commercial Room AC replacement rates, the Residential assumption is used; 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.

$$= 10.5^{418}$$

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption).⁴¹⁹

For example, for a room air conditioner removed from service in a multifamily setting in Burlington:

$$\begin{aligned} \Delta kWh &= ((466 * 8500)/(9.8/1.01 * 1,000)) - (0.76 * (466 * 8500)/(10.9 * 1,000)) \\ &= 138.9 kWh \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure
= 30%⁴²⁰

Other variables as defined above

For example, for a room air conditioner removed from service in a multifamily setting in Burlington:

$$\begin{aligned} \Delta kW &= (138.9/466) * 0.3 \\ &= 0.0894 kW \end{aligned}$$

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: NR-APL-RACR-V03-230101

SUNSET DATE: 1/1/2026

⁴¹⁸ 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.

⁴¹⁹ 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'.

⁴²⁰ In the absence of empirical evidence for commercial room AC usage in Iowa, the Residential assumption is used as a proxy; Consistent with coincidence factors found in:

RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

(http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RA_C.pdf)

3.3.22. Steam Trap Replacement or Repair

DESCRIPTION

This measure applies to the repair or replacement of failed steam traps on HVAC steam distribution systems. Faulty steam traps can allow excess steam to escape, wasting the energy used to generate steam and increasing the amount of steam generated. The measure is applicable to steam systems in commercial, industrial, and multifamily buildings.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is a repaired, rebuilt, or replaced steam trap.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a failed steam trap that needs to be repaired, rebuilt, or replaced as confirmed by a steam trap survey. No minimum leak rate is required – qualifying failed steam traps may be failed closed, partially open, or completely open.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 6 years.⁴²¹

DEEMED MEASURE COST

Measure cost depends on building type (commercial or industrial) and maximum steam system operating pressure (psig).

Steam System	Total Installed Cost (per Steam Trap) ⁴²²
Commercial (all operating pressures)	\$177
Industrial, ≤ 15 psig	\$280
Industrial, > 15 ≤ 30 psig	\$300
Industrial, > 30 ≤ 125 psig	\$323
Industrial, > 125 ≤ 200 psig	\$415
Industrial, > 200 ≤ 250 psig	\$275
Industrial, > 250 psig	Custom

LOADSHAPE

Loadshape NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

⁴²¹Measure life from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.

⁴²²Steam trap costs from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011. Measure cost includes installation cost of \$100 per trap, from Implement a Sustainable Steam-Trap Management Program, America Institute of Chemical Engineers, January 2014.

ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = LeakRate \times H_{vap} \times Hours_{Heat} \times \%Leak / EFF_{Heat} / 100,000$$

Where:

LeakRate = Average steam loss rate (lb/hr) per leaking trap
 = $24.24 \times (P_{Inlet} + 14.7) \times D^2 \times \%Adjust$

Where:

24.24 = Constant from Napier’s equation (lb/(hr-psia-in²))

P_{Inlet} = Steam trap inlet pressure (psig)
 = Actual

14.7 = Atmospheric pressure (psia)

D = Diameter of steam trap orifice (in)
 = Actual

%Adjust = Adjustment factor (%) to reduce the maximum theoretical steam flow to the average steam flow
 = 50%⁴²³

H_{vap} = Heat of vaporization of steam (Btu/lb)
 = Use values from table below, based on steam trap inlet pressure (psig):⁴²⁴

P _{Inlet} (psig)	H _{vap} (Btu/lb)
2	966
5	960
10	952
15	945
20	939
25	934
30	929
40	926
50	912
60	905
70	898
80	892
90	886

⁴²³ Enbridge adjustment factor, from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.

⁴²⁴ Heat of vaporization values from Steam Tables, Power Plant Service, Inc.

P _{Inlet} (psig)	H _{vap} (Btu/lb)
100	880
110	875
120	871
125	868
130	866
140	862
150	857
160	853
180	845
200	834
225	829
250	820

Hour_{SHeat} = Custom entry, annual operating hours of steam plant

%Leak = Percentage of leaking or blow-through steam traps

= 1.0 when applied to the replacment of an individual leaking trap. If a number of steam traps are replaced and the system has not been audited, %Leak is applied to reflect the assumed percentage of steam traps that were actually leaking and in need of replacement. Use 27% for commerical customers and 16% for industrial customers.⁴²⁵

EFF_{Heat} = Boiler efficiency (%)

= Actual operating efficiency.

100,000 = Factor to convert Btus to therms

For example, replacing a single failed steam trap with a 0.125 inch orifice diameter operating on a 30 psi system with 75% efficiency that operates 4,500 hours annually in a small retail setting will save:

$$\Delta\text{Therms} = (24.24 * (30 + 14.7) * 0.125^2 * 0.5) * 929 * 4,500 * 1.0 / (0.75 * 100,000)$$

$$= 471.8 \text{ Therms}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * \text{GCF}$$

Where:

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴²⁶	Model Source
Convenience	1.6310%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4240%	eQuest

⁴²⁵ % Leak values from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.

⁴²⁶ Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF ⁴²⁶	Model Source
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1745%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁴²⁷	1.4623%	N/A

For example, replacing a single failed steam trap with a 0.125 inch orifice diameter operating on a 30 psi system with 75% efficiency that operates 4,500 hours annually in a small retail setting will save:

$$\begin{aligned} \Delta\text{Therms} &= 471.8 * 0.0140550 \\ &= 6.6311 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-STRE-V03-220101

SUNSET DATE: 1/1/2026

⁴²⁷ For weighting factors, see HVAC variable table in section 3.3.

3.3.23. Electric HVAC Tune-up

DESCRIPTION

This measure is for the tune-up of electric cooling equipment, such as a unitary or split system air conditioner or a central air source or geothermal heat pump. This should not be used for water based systems such as chillers. The tune-up will improve performance by inspecting, cleaning, and adjusting the system for correct and efficient operation. An air conditioning system that is operating as designed saves energy and provides adequate cooling and comfort to the conditioned space. Heating savings are not currently characterized, however we hope to be able to add a much wider range of fault conditions based on NRELs recent modeling work through OpenStudio in a future cycle.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a unitary or split system air conditioner at least 3 tons in capacity. The measure assumes that a certified technician performs the following items:

- Check refrigerant charge
- Identify and repair leaks if refrigerant charge is low
- Measure and record refrigerant pressures
- Measure and record temperature drop at indoor coil
- Clean condensate drain line
- Clean outdoor coil and straighten fins
- Clean indoor and outdoor fan blades
- Clean indoor coil with spray-on cleaner and straighten fins
- Repair damaged insulation – suction line
- Change air filter
- Measure and record blower amp draw

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be an AC system that that does not have a standing maintenance contract or a tune up within in the past 36 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 3 years.⁴²⁸

DEEMED MEASURE COST

A copy of contractor invoices that detail the work performed, as well as additional labor and parts to improve/repair air conditioner performance should be submitted to the program and used as the measure cost.

LOADSHAPE

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

⁴²⁸ 3 years is given for “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”. DEER2014 EUL Table.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Capacity_{Cool} * [(1/EER_{before}) - (1/EER_{after})] * EFLH}{1000}$$

Where:

- Capacity_{Cool} = output capacity of the cooling equipment in Btu per hour (note 1 ton = 12,000Btu/hr)
= Actual
- EER_{before} = Energy Efficiency Ratio of the baseline equipment prior to tune-up
= Actual⁴²⁹
- EER_{after} = Energy Efficiency Ratio of the baseline equipment after to tune-up
= Actual
- EFLH = Equivalent Full Load Hours for cooling in Existing Buildings are provided in section 3.3 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methodology can be used:

$$\Delta kWh = (Capacity_{Cool}) / (1000 * EER_{rated}) * EFLH * \%Savings$$

Where:

- %Savings = Deemed percent savings per Tune-Up component. These are additive multiple components are performed (total provided below):⁴³⁰

Tune-Up Component	% savings
Correct Refrigerant Charge	2%
Clean condenser coils	1%
Clean evaporator coils	1%
If full tune up performed	5%

⁴²⁹ In the context of this measure Energy Efficiency Ratio (EER) refers to field-measured steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). The cooling capacity may be derived using either refrigerant or air-side measurements. The measurement is performed at the outdoor and indoor environmental conditions that are present at the time the tune-up is being performed, and should be normalized using a correction function to the AHRI 210/240 Standard test conditions. The correction function should be developed based on manufacturer’s performance data. Care must be taken to ensure the unit is fully loaded and operating at or near steady-state.

⁴³⁰ Savings estimates are determined by applying each maintenance issue (high/low refrigerant charge, dirty condenser coil, dirty evaporator coil and all three combined) to the base maintained Office OpenStudio model and comparing electricity consumption.

For example, a 12 EER, 60,000 Btuh rooftop air conditioner on a restaurant in Burlington receives a full tune-up:

$$\begin{aligned} \Delta kWh &= (60000 / (1000 * 12)) * 1,397 * 5\% \\ &= 349 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁴³¹	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ⁴³²	92.3%	N/A

For example, a 12 EER, 60,000 Btuh rooftop air conditioner on a restaurant in Burlington receives a full tune-up:

$$\begin{aligned} \Delta kW &= 349 / 1397 * 0.996 \\ &= 0.2488 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁴³¹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁴³² For weighting factors, see HVAC variable table in section 3.3.

MEASURE CODE: NR-HVC-ACTU-V01-210101

SUNSET DATE: 1/1/2025

3.3.24. Electric Chiller Tune-up

DESCRIPTION

This measure is for the tune-up of electric water-based chiller systems. Proper system tune-up and maintenance ensures refrigerant charges and airflows through evaporator coils have been properly tested and correctly adjusted. Restoring a chiller system so that it operates as originally designed can save energy and provide adequate cooling and comfort to the conditioned space. Note: air-based chiller systems should follow 3.3.23 Electric HVAC Tune-up.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a chiller system at least 10 tons in capacity. The measure assumes that a certified technician performs the following items:

- Check refrigerant charge
- Identify and repair leaks if refrigerant charge is low
- Measure and record refrigerant pressures
- Clean condenser and evaporator tubes
- Check oil level and pressure on all components
- Check pressure controls
- Inspect and clean/change air filter

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be a chiller system that that does not have a standing maintenance contract or a tune up within in the past 36 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 3 years.⁴³³

DEEMED MEASURE COST

A copy of contractor invoices that detail the work performed, as well as additional labor and parts to improve/repair air conditioner performance should be submitted to the program and used as the measure cost.

LOADSHAPE

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

⁴³³ 3 years is given for “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”. DEER2014 EUL Table.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Capacity_{Cool} * [(1/EER_{before}) - (1/EER_{after})] * EFLH}{1000}$$

Where:

Capacity_{Cool} = output capacity of the chiller in Btu per hour (note 1 ton = 12,000Btu/hr)
 = Actual, nameplate

EER_{before} = Energy Efficiency Ratio of the chiller prior to tune-up (note EER = 12 / kW/ton)
 = Actual, as measured⁴³⁴

EER_{after} = Energy Efficiency Ratio of the chiller after tune-up
 = Actual, as measured

EFLH = Equivalent Full Load Hours for cooling in Existing Buildings are provided in section 3.3 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methodology can be used:

$$\Delta kWh = (Capacity_{Cool}) / (1000 * EER_{rated}) * EFLH * \%Savings$$

Where:

EER_{rated} = Nameplate Energy Efficiency Ratio of the chiller

%Savings = Deemed percent savings per Tune-Up component.⁴³⁵
 = 5%

For example, a 12 EER, 600,000 Btuh chiller serving a warehouse in Burlington receives a full tune-up:

$$\begin{aligned} \Delta kWh &= (600000 / (1000 * 12)) * 1,032 * 5\% \\ &= 2,580 kWh \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

⁴³⁴ In the context of this measure Energy Efficiency Ratio (EER) refers to field-measured steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). The cooling capacity may be derived using either refrigerant or air-side measurements. The measurement is performed at the outdoor and indoor environmental conditions that are present at the time the tune-up is being performed, and should be normalized using a correction function to the AHRI 210/240 Standard test conditions. The correction function should be developed based on manufacturer’s performance data. Care must be taken to ensure the unit is fully loaded and operating at or near steady-state. ASHRAE Standard 184 is a recommended resource for field testing liquid chiller performance.

⁴³⁵ Consistent with deemed approach in 3.3.23 and supported by literature review.

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

Where:

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁴³⁶	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ⁴³⁷	92.3%	N/A

For example, a 12 EER, 600,000 Btuh chiller serving a warehouse in Burlington receives a full tune-up:

$$\begin{aligned} \Delta kW &= 2580 / 1032 * 0.779 \\ &= 1.9475 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-CHTU-V01-220101

SUNSET DATE: 1/1/2026

⁴³⁶ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁴³⁷ For weighting factors, see HVAC variable table in section 3.3.

3.3.25. 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 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 characterization is limited to estimating the impacts associated with space heating loads only and does not apply to scenarios where a gas-fired heat pump is used to meeting cooling and/or DHW loads. A custom analysis should be used in such a case.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a natural gas fired heat pump used for space heating, not process or DHW, and boiler efficiency rating must meet the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency source is a natural gas non-condensing boiler used for space heating, not process, meeting the federal equipment standards. The current Federal Standard minimum AFUE rating is 84% for boilers <300,000 Btu/hr capacity,⁴³⁸ 80% E_T for boilers $\geq 300,000$ Btu/h and $\leq 2,500,000$ Btu/h, and 82% E_C for boilers >2,500,000 Btu/h.⁴³⁹

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.⁴⁴⁰

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is:⁴⁴¹

$$\$0.115 * \text{Capacity}_{\text{out}}$$

Where:

$$\text{Capacity}_{\text{out}} = \text{Nominal heating output capacity (Btu/hr) of gas-fired heat pump}$$

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

LOADSHAPE

Loadshape NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Loadshape NREH01:16 - Nonresidential Electric Heat (by Building Type)

⁴³⁸ Code of Federal Regulations, 10 CFR 430.32(e)(2). <http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol3/pdf/CFR-2011-title10-vol3-sec430-32.pdf>. Future energy conservation standards are under development.

⁴³⁹ Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

⁴⁴⁰ Consistent with assumption for a conventional space heat boiler.

⁴⁴¹ Based on a first cost estimates from GTI, which lists gas heat pumps as \$100-\$180/MBH output and conventional boilers as \$15-35/MBH. The difference of the range averages (\$140 - \$25) is used to establish the incremental costs based on MBH output.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Gas-fired heat pumps consume electricity during their operation and therefore result in increased site electric load.

$$\Delta kWh = \frac{-Power * EFLH}{1000}$$

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 capacity⁴⁴²
- EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{EfficiencyRating (EE)}{EfficiencyRating (base)} - 1 \right)}{100,000}$$

Where:

- EFLH = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
- Capacity = Nominal Heating Input Capacity (Btu/hr) gas-fired heat pump
= Actual
- EfficiencyRating(base) = Baseline equipment efficiency rating, depending on boiler input capacity.

Boiler Input Capacity	Efficiency Rating
<300,000 Btu/hr	84% AFUE ⁴⁴³
≥300,000 Btu/h and ≤2,500,000 Btu/h	80% E _T ⁴⁴⁴
>2,500,000 Btu/h	82% E _C ⁴⁴⁵

- EfficiencyRating(EE) = Efficient equipment efficiency rating
= Actual. If unknown, assume 130%⁴⁴⁶
- 100,000 = Conversion of Btu to Therms

⁴⁴² Based on average of power requirements for Robur K18 (0.004341794 W/Btu/hr) and GAHP-A (0.005960768 W/Btu/hr)

⁴⁴³ Code of Federal Regulations, 10 CFR 430.32(e)(2). <http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol3/pdf/CFR-2011-title10-vol3-sec430-32.pdf>. Future energy conservation standards are under development.

⁴⁴⁴ Thermal Efficiency. Code of Federal Regulations, 10 CFR 431.87.

⁴⁴⁵ Combustion Efficiency. Code of Federal Regulations, 10 CFR 431.87

⁴⁴⁶ Based on findings presented Brio and GTI’s Gas Heat Pump Roadmap Industry White Paper, November 2019.

For example, for a 150,000 Btu/hr gas-fired heat pump with AFUE 130% in at an existing large office building in unknown location:

$$\begin{aligned} \Delta kWh &= -0.0052 * 150,000 * 1549 / 1000 \\ &= -1,208.22 \text{ kWh} \\ \Delta Therms &= 1549 * 150,000 * ((1.3/0.84)-1) / 100,000 \\ &= 1272.4 \text{ Therms} \end{aligned}$$

PEAK GAS SAVINGS

$$\Delta Peak Therms = \Delta Therms * GCF$$

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁴⁴⁷	Model Source
Convenience	1.631%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4240%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1745%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁴⁴⁸	1.4623%	N/A

For example, for a 150,000 Btu/hr gas-fired heat pump with AFUE 130% at an existing large office building in unknown location:

$$\begin{aligned} \Delta Peak Therms &= 1272.4 * 0.013082 \\ &= 16.6455 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁴⁴⁷ Calculated as the percentage of total savings in the maximum saving day, from models.

⁴⁴⁸ For weighting factors, see HVAC variable table in section 3.3.

MEASURE CODE: NR-HVC-GFHP-V01-220101

SUNSET DATE: 1/1/2025

3.3.26. Variable Refrigerant Flow (VRF) Systems

DESCRIPTION

This measure applies to the installation of a variable refrigerant flow (VRF) system in lieu of a traditional heat pump system. This measure could apply to replacing an existing unit at the end of its useful life, or installation of a new unit in a new or existing building.

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.

Variable Refrigerant Flow (VRF) systems are typically all-electric systems that use heat pumps to provide space heating and cooling to building spaces. They can serve multiple zones in a building, each with different heating and cooling requirements. VRF systems modulate the amount of refrigerant sent to each zone in accordance with conditioning requirements. In contrast, conventional HVAC systems deliver air or water and operate on a full-on or full-off schedule. Compared with air-to-air heat pumps, VRF offers energy savings due to better part-load efficiencies, heat recovery, smaller zones, and reduced duct losses

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be, at minimum, code compliant VRF equipment.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a code-compliant heat pump system, with components meeting the energy efficiency requirements set forth by the Code of Federal Regulations and the International Energy Conservation Code (IECC) 2012.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁴⁴⁹

DEEMED MEASURE COST

For analysis purposes, the incremental capital cost should be determined on a site-specific basis, due to the variable nature of design requirements and the fact that the baseline to improved case system design may not be a simple component for component replacement. If not possible to determine, an incremental cost of \$4.5/SQFT of building area should be used as a best estimate on incremental cost to install a VRF system⁴⁵⁰.

LOADSHAPE

Loadshape NREP01:16 - Nonresidential Electric Heat Pump (by Building Type)

Loadshape NREV01:16 – Nonresidential Ventilation (by Building Type)

Algorithm

CALCULATION OF SAVINGS

Whole building modeling was performed using OpenStudio to determine savings estimates for the following building

⁴⁴⁹Consistent with measure lifetime assumptions for measure 3.3.4 Heat Pump Systems.

⁴⁵⁰ ACEEE 2016 Summer Study Paper: Utility Program Cost Effectiveness of Variable Refrigerant Flow Systems. Incremental cost estimates from the Washington State University Extension Energy Program are listed as \$12-\$15 per square foot for a code-minimum system and \$18 per square foot for a VRF system. \$18 - \$13.5 (average of \$12 and \$15) = \$4.5 per square foot referenced in the TRM.

types: hotel, primary school, secondary school, midrise apartment, and office. Other building types should not use this characterization for savings estimates but should be noted so that the characterization can be expanded to include them in the future.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = SQFT * (Cool + Heat + Fan)$$

Where:

SQFT = Building square footage
 = Actual

Cool, Heat, Fan = Savings factors for cooling, heating and fan energy, respectively. As indicated in the following table and specific to building classification. Established using OpenStudio modeling. Units are kWh/SQFT

Weather Zone	Building Type	Heat (kWh/SQFT)	Cool (kWh/SQFT)	Fan (kWh/SQFT)
Zone 5 (Burlington)	Hotel - Large	-0.33346	0.552849	2.016529
Zone 5 (Burlington)	Hotel - Small	-0.77062	0.461791	1.269607
Zone 5 (Burlington)	Primary School	-0.36603	0.419165	0.276555
Zone 5 (Burlington)	Secondary School	-0.33236	0.537251	0.384101
Zone 5 (Burlington)	Midrise Apartment	0.013104	0.226305	0.494401
Zone 5 (Burlington)	Office - Large	-0.07755	0.110837	1.794719
Zone 5 (Burlington)	Office - Medium	-0.30054	0.307518	0.379756
Zone 5 (Burlington)	Office - Small	-0.39407	0.123924	0.099816
Zone 6 (Mason City)	Hotel - Large	-0.41508	0.094191	2.067151
Zone 6 (Mason City)	Hotel - Small	-1.03922	0.311281	1.284555
Zone 6 (Mason City)	Primary School	-0.46795	0.256572	0.266787
Zone 6 (Mason City)	Secondary School	-0.0534	0.226952	0.268517
Zone 6 (Mason City)	Midrise Apartment	0.059517	0.22218	0.485346
Zone 6 (Mason City)	Office - Large	-0.12351	-0.21143	1.662037
Zone 6 (Mason City)	Office - Medium	-0.36804	0.197064	0.389187
Zone 6 (Mason City)	Office - Small	-0.59192	0.150707	0.350445
Average/unknown	Hotel - Large	-0.33207	0.402723	2.035629
Average/unknown	Hotel - Small	-0.85803	0.400139	1.29791
Average/unknown	Primary School	-0.72377	0.348614	0.275022
Average/unknown	Secondary School	-0.40465	0.387509	0.332844
Average/unknown	Midrise Apartment	0.041651	0.206514	0.515703
Average/unknown	Office - Large	-0.07378	-0.05851	1.766358
Average/unknown	Office - Medium	-0.28178	0.26853	0.398483
Average/unknown	Office - Small	-0.41448	0.116795	0.109849

For example, a 50,000 SQFT medium office in Zone 6 installing a VRF system instead of traditional heat pumps saves:

$$\begin{aligned} \Delta kWh &= 50000 * (-0.36804 + 0.197064 + 0.389187) \\ &= 10,910.6 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \left[\frac{SQFT * Cool}{LH_{cooling}} \right] * CF$$

Where:

LH_{cooling} = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁴⁵¹	Model Source
Education	96.7%	OpenStudio
Lodging (use for Hotel)	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio

For example a 50,000 SQFT medium office in Zone 6 installing a VRF system instead of traditional heat pumps saves (note: using Cooling Load Hours for Large Office):

$$\begin{aligned} \Delta kW &= ((50000 * 0.197064) / 4457) * 0.988 \\ &= 2.1842 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-VRFS-V01-220101

SUNSET DATE: 1/1/2025

⁴⁵¹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

3.3.27. Demand Controlled Ventilation

DESCRIPTION

Demand control ventilation (DCV) adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create. DCV is part of a building's ventilation system control strategy. It may include hardware, software, and controls as an integral part of a building's ventilation design. Active control of the ventilation system provides the opportunity to reduce heating and cooling energy use.

The primary component is a control sensor to communicate either directly with the economizer or with a central computer. The component is most typically a carbon dioxide (CO₂) sensor, occupancy sensor, or turnstile counter. This measure is applicable to multiple building types, and savings are classified by the specific building types defined in the Illinois TRM. This measure is modeled to assume night time set backs are in operation and minimum outside air is being used when the building is unoccupied. Systems that have static louvers or that are open at night will likely have greater savings by using the custom program.

Demand controlled ventilation controls can also be added to the exhaust fans to enclosed parking garages. The fans modulate the ventilation airflow based on pollutant concentrations (primarily carbon monoxide) in the space.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by new CO₂ sensors installed on return air systems where no other sensors were previously installed. For heating savings, this measure does not apply to any system with terminal reheat (constant volume or variable air volume). For terminal reheat system a custom savings calculation should be used.

DEFINITION OF BASELINE EQUIPMENT

The base case for this measure is a space with no demand control capability. The current code minimum for outside air (OA) is 17 CFM per occupant (ASHRAE 62.1 - 2016) which is the value for office space assumed in this measure.

This measure does not apply to packaged single-zone (PSZ) rooftop units with functioning economizers.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 15 years.⁴⁵²

DEEMED MEASURE COST

The deemed measure cost is assumed to be the full cost of installation of a DCV retrofit including sensor cost (\$500) and installation (\$1000 labor) for a total of \$1,500.⁴⁵³

LOADSHAPE

Loadshapes NREV01:16 – Nonresidential Ventilation (by Building Type)

COINCIDENCE FACTOR

N/A

Algorithm

⁴⁵² SWHC006-01, California Technical Forum, 2019.

⁴⁵³ Discussion with vendors. ILSAG, IL TRM v.11, Measure 4.4.19.

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas,

$$\Delta kWh = \text{Condition Space}/1000 * SF_{cooling}$$

For facilities heated by heat pumps,

$$\Delta kWh = \text{Condition Space}/1000 * SF_{cooling} + \text{Condition Space}/1000 * SF_{Heat HP}$$

For facilities heated by electric resistance,

$$\Delta kWh = \text{Condition Space}/1000 * SF_{cooling} + \text{Condition Space}/1000 * SF_{Heat ER}$$

Where:

- Conditioned Space = actual square footage of conditioned space controlled by sensor
- SF_{cooling} = Cooling Savings Factor
= value in table below based on building type and weather zone
- SF_{Heat HP} = Heating Savings factor for facilities heated by Heat Pump (HP)
= value in table below based on building type and weather zone
- SF_{Heat ER} = Heating Savings factor for facilities heated by Electric Resistance (ER)
= value in table below based on building type and weather zone

Saving Factor Tables⁴⁵⁴

Building Type	SF _{cooling} (kWh/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines)
Office - Low-rise	270	207	365
Office - Mid-rise	212	164	288
Office - High-rise	252	194	342
Religious Building	801	555	984
Restaurant	518	362	643
Retail - Department Store	371	282	496
Retail - Strip Mall	258	196	343
Convenience Store	333	258	450
Elementary School	371	260	463
High School	363	254	453
College/University	427	291	537
Healthcare Clinic	352	254	447
Lodging	383	296	516
Manufacturing	165	127	223
Special Assembly Auditorium	604	409	733

⁴⁵⁴ Savings are calculated on an annual basis for each given temperature zone in Illinois and converted using TMY3 weather data to Iowa temperature zones via a heating degree day and cooling degree day analysis between respective IL and IA temperature zones.

Building Type	SF _{cooling} (kWh/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines)
Default	379	274	486

Building Type	SF _{Heat HP} (kWh/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines)
Office - Low-rise	204	283	201
Office - Mid-rise	137	189	135
Office - High-rise	184	254	182
Religious Building	1,332	1,818	1,309
Restaurant	945	1,286	944
Retail - Department Store	328	444	323
Retail - Strip Mall	220	297	211
Convenience Store	159	217	160
Elementary School	573	792	562
High School	559	773	548
College/University	1,106	1,527	1,094
Healthcare Clinic	393	539	389
lodging	179	247	181
Manufacturing	114	157	112
Special Assembly Auditorium	1,596	2,137	1,535
Default	535	731	525

Building Type	SF _{Heat ER} (kWh/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines)
Office - Low-rise	612	848	604
Office - Mid-rise	411	568	405
Office - High-rise	552	763	544
Religious Building	3,996	5,452	3,926
Restaurant	2,834	3,859	2,833
Retail - Department Store	986	1,330	969
Retail - Strip Mall	659	890	634
Convenience Store	477	652	479
Elementary School	1,719	2,377	1,684
High School	1,675	2,319	1,642
College/University	3,318	4,582	3,280
Healthcare Clinic	1,178	1,617	1,166
lodging	538	743	541
Manufacturing	342	470	337

Building Type	SF _{Heat ER} (kWh/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines)
Special Assembly Auditorium	4,789	6,413	4,605
Default	1,606	2,193	1,577

For example, for a 7,500 SqFt of low-rise office space in Burlington with gas heat.

$$\Delta kWh = 7,500 / 1000 * 270$$

$$= 2,025 kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

NA

FOSSIL FUEL SAVINGS

$$\Delta \text{therms} = \text{Condition Space}/1000 * SF_{\text{Heat Gas}}$$

Where:

SF_{Heat Gas} = value in table below based on building type and weather zone.⁴⁵⁵

Building Type	SF _{Heat Gas} (Therm/1000 SqFt)		
	Zone 5 (Burlington)	Zone 6 (Mason City)	Unknown (Des Moines)
Office - Low-rise	26	36	26
Office - Mid-rise	18	24	18
Office - High-rise	24	32	24
Religious Building	170	233	168
Restaurant	121	165	121
Retail - Department Store	42	56	41
Retail - Strip Mall	28	38	27
Convenience Store	20	28	20
Elementary School	73	101	72
High School	71	99	70
College/University	141	195	140
Healthcare Clinic	51	69	50
lodging	23	31	23
Manufacturing	15	20	15
Special Assembly Auditorium	204	274	196
Default	69	94	67

⁴⁵⁵ The natural gas energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by ASHRAE 62.1 and 90.1, respectively. Building input parameters like square footage, equipment efficiencies and occupancy match those used in the EFLH calculations. Reference calculation found in Demand Control Ventilation 12-30-13.xls.

For example, for a 7500 SqFt of low-rise office space in Burlington.

$$\begin{aligned}\Delta\text{Therms} &= 7,500/1,000 * 26 \\ &= 195 \text{ Therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-DCV-V01-240101

Sunset Date: 1/1/2027

3.4. Lighting

The nonresidential lighting measures use a standard set of variables for hours of use, waste heat factors, coincidence factors, and HVAC interaction effects. This table has been developed based on OpenStudio and eQuest modeling performed by VEIC, unless otherwise noted. The models, prototype building descriptions, methodology documentation, and final results can be found on the Iowa TRM SharePoint Site (TRM Reference Documents; Non Residential; Modeling). For ease of review, the table is included here and referenced in each measure.

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized. For the specific assumptions used in each model, refer to table in the [“IA Prototype Building Descriptions”](#) file in the SharePoint folder referenced above.

Building Type	HOU	WHFe ⁴⁵⁶	WHFd ⁴⁵⁷	CF ⁴⁵⁸	WHFh ⁴⁵⁹	IFTherm s Eff = 80%	IFkWh (resistance) COP = 1	IFkWh (heat pump) COP = 2.3	Model Source
General Agricultural Animal Housing and Warehousing	2920	1.0	1.0	61.8%	0.000	0.000	0.000	0.000	eQuest
Agriculture – Chicken Broilers ⁴⁶⁰	3,251	1.0	1.0	76.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Chicken Breeders	4,606	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Chicken Layers	4,914	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Turkey Hens	2,231	1.0	1.0	76.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Turkey Toms	5,351	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a

⁴⁵⁶ Determined as the total building electrical savings divided by the lighting electrical savings. Note that effects of heat pump, electric heat or dehumidification were removed to isolate only the cooling waste heat impacts.

⁴⁵⁷ Determining WHFd for weather dependent, interactive measures uses the same two energy model runs as WHFe. The calculation uses the difference in average total peak hour demand divided by the difference in average lighting peak hour demand.

⁴⁵⁸ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁴⁵⁹ This unit-less factor is calculated based on changes in peak heating load (equipment output) relative to the change in peak lighting demand. This method allows universal applicability to various heating fuels and efficiencies. The appropriate IF can be calculated by applying the correct conversion factor and heating system efficiency without needing multiple modeling runs to represent various heating fuels.

⁴⁶⁰ Agriculture lighting loadshapes, operational hours, and HVAC interactive factors are sourced from the 2021 Illinois Statewide Technical Reference Manual for Energy Efficiency, version 9.0, September 2020. These values were developed based on field experience and research material for the general agriculture, indoor agriculture, poultry and dairy commodities. Due to livestock housing having little to no mechanical cooling systems, waste heat cooling and associated demand factors were assumed to be 1.00.

Building Type	HOU	WHFe ⁴⁵⁶	WHFd ⁴⁵⁷	CF ⁴⁵⁸	WHFh ⁴⁵⁹	IFTherm s Eff = 80%	IFkWh (resista nce) COP = 1	IFkWh (heat pump) COP = 2.3	Model Source
Agriculture – Turkey Breeder Toms	4,396	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Turkey Breeder Hens	5,446	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Agriculture – Dairy Long Day Lighting	6,205	1.0	1.0	95.0%	0.000	0.000	0.000	0.000	n/a
Convenience	4630	1.14	1.31	100.0%	0.36	0.015	0.36	0.16	eQuest
Education	1877	1.07	1.48	65.27%	0.45	0.019	0.45	0.20	OpenStudio
Exterior Lighting	4676	1.0	1.0	0%	0.000	0.000	0.000	0.000	OpenStudio
Grocery	4663	1.02	1.20	82.11%	0.30	0.013	0.30	0.13	OpenStudio
Health	3806	1.09	1.69	67.00%	0.35	0.015	0.35	0.15	OpenStudio
Hospital	6520	1.16	1.26	55.95%	0.18	0.008	0.18	0.08	OpenStudio
Industrial	2850	1.02	1.02	91.80%	0.37	0.016	0.37	0.16	eQuest
Lodging	3061	1.23	1.47	61.07%	0.19	0.008	0.19	0.08	OpenStudio
Multifamily	3061	1.13	1.15	71.17%	0.44	0.019	0.44	0.19	OpenStudio
Office - Large	2920	1.17	1.04	60.20%	0.29	0.013	0.29	0.13	OpenStudio
Office - Small	2920	1.10	1.28	51.79%	0.33	0.014	0.33	0.15	OpenStudio
Religious	2412	1.12	1.32	66.00%	0.46	0.020	0.46	0.20	eQuest
Restaurant	5443	1.10	1.07	100.00%	0.23	0.010	0.23	0.12	OpenStudio
Retail - Large	4065	1.09	1.13	100.00%	0.28	0.012	0.28	0.16	eQuest/Open Studio
Retail - Small	3694	1.09	1.20	100.00%	0.36	0.015	0.36	0.16	OpenStudio
Warehouse	2920	1.00	1.00	61.8%	0.00	0.000	0.00	0.00	eQuest/Open Studio
Nonresidential Average ⁴⁶¹	3065	1.07	1.20	69.07%	0.27	0.011	0.27	0.12	N/A
Unconditioned building	As above	1.0	1.0	As above	0.000	0.000	0.000	0.000	N/A
Refrigerated Cases ⁴⁶²	As above	1.29	1.29	As above	0.000	0.000	0.000	0.000	N/A
Freezer Cases ⁴⁶³	As above	1.50	1.50	As above	0.000	0.000	0.000	0.000	N/A

⁴⁶¹ For weighting factors, see HVAC variable table in section 3.3.

⁴⁶² WHFe and WHFd for refrigerated case lighting is 1.29 (calculated as $(1 + (1.0 / 3.5))$). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5 COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak.

⁴⁶³ WHFe and WHFd for freezer case lighting is 1.50 (calculated as $(1 + (1.0 / 2.0))$). Based on the assumption that all lighting in freezer cases is mechanically cooled, with a typical 2.0 COP freezer system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak.

3.4.1. 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.

3.4.2. 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.

3.4.3. LED Lamp Standard

DESCRIPTION

LEDs lighting systems convert electricity to light and emit more lumens per watt when compared to baseline EISA incandescent, halogen, or compact fluorescent lamps. In addition, LED’s inherent directionality reduces or eliminates the need for a reflector to direct light, thereby reducing or eliminating fixture efficiency losses. These factors make LEDs a highly efficient alternative to standard interior and exterior lighting options.

This specific characterization provides savings assumptions for LED lamps that replace standard screw-in connections (e.g., A-Type lamp) such as interior/exterior omnidirectional lamp options.

This characterization assumes that the LED is installed in a commercial location. This is therefore appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), utilities should develop an assumption of the Residential vs. 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.

The v7 TRM continues to take the approach of using a market based baseline for the measure, however programs should end support of large scale retail or kit programs by July 2023. Direct Install where we can be sure the LED is replacing inefficient lighting may want to ramp down more slowly. The lifetime of any 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: TOS, 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 LED screw-based lamps must be ENERGY STAR qualified based upon the v2.1 ENERGY STAR specification for lamps

(https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification_1.pdf) or CEE Tier 2 qualified. Specifications are as follows:

Efficiency Level	Lumens / watt	
	CRI<90	CRI≥90
ENERGY STAR v2.1	80	70

CEE Tier 2 ⁴⁶⁴	95	80
---------------------------	----	----

Qualification could also be based on the Design Light Consortium’s qualified product list.⁴⁶⁵

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 31% EISA qualified halogen or incandescent and 1% CFL and 68%LED.⁴⁶⁶ The baseline is forecast to continue to shift towards LEDs and therefore a mid-life adjustment is provided. For Direct Install programs use the actual wattage being replaced.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of the product is the lamp life in hours divided by operating hours per year. Depending on operating conditions (currents and temperatures) and other factors (settings and building use), LED rated life is assumed to be 20,230.⁴⁶⁷ 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 in 2023 should therefore be two years.

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:⁴⁶⁸

Lamp Type	CRI	Product Type	Cost	Incremental Cost
Standard A-lamp	<90	Baseline	\$2.60	n/a
		ESTAR LED	\$3.16	\$0.56
		CEE T2 LED	\$3.29	\$0.69
	>=90	Baseline	\$2.95	n/a
		ESTAR LED	\$3.67	\$0.72
		CEE T2 LED	\$3.75	\$0.80

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * WHFe * ISR$$

Where:

⁴⁶⁴ Also required to have rated life of 25,000 hours and dimming capability.

⁴⁶⁵ <https://www.designlights.org/QPL>

⁴⁶⁶ 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’.

⁴⁶⁷ Average rated life of omnidirectional bulbs on the ENERGY STAR qualified products list as of April, 2020.

⁴⁶⁸ 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.

Watts_{Base} = Based on lumens of LED bulb installed as and includes blend of incandescent/halogen,⁴⁶⁹ CFL, and LED by weightings provided in table below.⁴⁷⁰ 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. A custom value can be entered if the configurations in the tables are not representative of the existing system.

Watts_{EE} = Actual wattage of LED purchased/installed. If unknown, use default provided below:⁴⁷¹

Lower Lumen Range	Upper Lumen Range	Inc/ Halogen 31%	CFL ⁴⁷² 1%	LED ⁴⁷³ 68%	Watts _{Base}	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
						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	1049	43	15.0	12.0	21.6	11.2	12.9	9.5	11.2	10.4	8.8	12.2	10.4
1050	1489	53	21.2	16.9	28.1	15.9	18.1	13.4	15.9	12.3	10.0	14.8	12.3
1490	2600	72	34.1	27.3	41.2	25.6	29.2	21.5	25.6	15.6	12.0	19.7	15.6
2601	3300	150	49.2	39.3	73.7	36.9	42.2	31.1	36.9	36.8	31.5	42.6	36.8
3301	3999	200	60.8	48.7	95.6	45.6	52.1	38.4	45.6	50.0	43.5	57.2	50.0
4000	6000	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 ⁴⁷⁴					23.2	12.4				10.8			

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR and CRI<90.

Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 3.4. If hours or building type are unknown, use the Nonresidential Average value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 3.4 for each building type. If unknown, use the Nonresidential Average value.

ISR = In Service Rate or the percentage of units rebated that get installed
 =100% if application form completed with sign off that equipment is not placed into storage. If sign off form not completed, assume the following:

⁴⁶⁹ Incandescent/Halogen wattage is based upon the post first phase of EISA.

⁴⁷⁰ 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'.

⁴⁷¹ 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,

⁴⁷² Baseline CFL watts are calculated using the midpoint of the lumen range and an assumed efficacy of 60 lumens/watt.

⁴⁷³ Baseline LED watts are calculated using the midpoint of the lumen range and an assumed efficacy of 75 lumens/watt.

⁴⁷⁴ Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

Program	Discounted In Service Rate (ISR) ⁴⁷⁵
Retail (Time of Sale) ⁴⁷⁶	89%
Direct Install ⁴⁷⁷ and Retrofit	97%

Heating Penalty:

If electrically heated building:⁴⁷⁸

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * WHFd * CF * ISR$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

CF = Summer Peak Coincidence Factor for measure is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):⁴⁷⁹

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTtherms)$$

Where:

IFTtherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4.

⁴⁷⁵ 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 “Non-Res Lighting ISR calculation_2019.xlsx” for more information.

⁴⁷⁶ The 1st year in service rate for Retail LEDs is a weighted average based on PY7 and PY9 evaluations from ComEd’s, Illinois commercial lighting program (BILD) and PY9 data from Ameren Illinois Instant Incentives program.

⁴⁷⁷ Consistent with CFL assumption. Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys; <http://www.ilsag.info/evaluation-documents.html>

⁴⁷⁸ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁴⁷⁹ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

If unknown, use the Nonresidential Average value.

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

= 190⁴⁸⁰

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-LEDA-V08-240101

SUNSET DATE: 1/1/2025

⁴⁸⁰ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

3.4.4. LED Lamp Specialty

DESCRIPTION

LEDs lighting systems convert electricity to light and emit more lumens per watt when compared to incandescent, halogen or compact fluorescent lamps. In addition, LED’s inherent directionality reduces or eliminates the need for a reflector to direct light, thereby reducing or eliminating fixture efficiency losses. These factors make LEDs a highly efficient alternative to standard interior and exterior lighting options.

This specific characterization provides savings assumptions for LED Directional, Decorative, and Globe lamps.

This characterization assumes that the LED is installed in a commercial location. This is therefore appropriate for commercially targeted programs, or, if the implementation strategy does not allow for the installation location to be known (e.g., an upstream retail program), 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 EISA qualified incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

A 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 v7 TRM continues to take the approach of using a market based baseline for the measure, however programs should end support of large scale retail or kit programs by July 2023. Direct Install where we can be sure the LED is replacing inefficient lighting may want to ramp down more slowly. The lifetime of any 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: TOS, 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 LED lamps must be ENERGY STAR qualified based upon the v2.1 ENERGY STAR specification for lamps

(https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification_1.pdf) or CEE Tier 2⁴⁸¹ qualified. Specifications are as follows:

Efficiency Level	Lamp Type	Lumens / watt	
		CRI<90	CRI≥90
ENERGY STAR v2.1	Directional	70	61
	Decorative / Globe	65	65
CEE Tier 2 ⁴⁸¹	Directional	85	70

⁴⁸¹ Also required to have dimming capability.

	Decorative / Globe	95	80
--	--------------------	----	----

Qualification could also be based on the Design Light Consortium’s qualified product list.⁴⁸²

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 27% EISA qualified halogen or incandescent and 73% baseline LED for decorative and globe lamps, and 5% EISA qualified halogen or incandescent and 95% baseline LED for decorative and globe lamps.⁴⁸³ Lamp types include those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (≤40W equivalent(We)), candelabra base (≤60We), vibration service bulb, decorative candle with medium or intermediate base (≤40We), shatter resistant, and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5” diameter and >40We), candle (shapes B, BA, CA >40We), candelabra base lamps (>60We), and intermediate base lamps (>40We). For Direct Install programs use the actual wattage being replaced.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The rated life for directional bulbs is assumed to be 25,042 hours and for decorative bulbs is 17,129 hours.⁴⁸⁴ 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 in 2023 should therefore be two years.

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:⁴⁸⁵

Bulb Type	CRI	Product Type	Cost	Incremental Cost
Directional	<90	Baseline	\$7.66	n/a
		ESTAR LED	\$7.80	\$0.14
		CEE T2 LED	\$18.96	\$11.30
	≥90	Baseline	\$7.47	n/a
		ESTAR LED	\$7.63	\$0.16
		CEE T2 LED	\$18.54	\$11.08
Decorative	<90	Baseline	\$6.28	n/a
		ESTAR LED	\$7.50	\$1.21
		CEE T2 LED	\$7.83	\$1.55
	≥90	Baseline	\$7.16	n/a
		ESTAR LED	\$8.69	\$1.54
		CEE T2 LED	\$9.08	\$1.92

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

⁴⁸² <https://www.designlights.org/QPL>

⁴⁸³ Based on 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’.

⁴⁸⁴ Average rated life of directional and decorative bulbs on the ENERGY STAR qualified products list as of April, 2020.

⁴⁸⁵ 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.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * WHFe * ISR$$

Where:

Watts_{Base} = Based on lumens of LED bulb installed and includes blend of incandescent/halogen,⁴⁸⁶ CFL and LED by weightings provided in table below.⁴⁸⁷ 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. A custom value can be entered if the configurations in the tables are not representative of the existing system.

Watts_{EE} = Actual wattage of LED purchased/installed. If unknown, use default provided below.⁴⁸⁸

⁴⁸⁶ Incandescent/Halogen wattage is based upon the ENERGY STAR specification for lamps (http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf) and the Energy Policy and Conservation Act of 2012.

⁴⁸⁷ 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’.

⁴⁸⁸ Watts_{EE} defaults are based upon the ENERGY STAR minimum luminous efficacy for the mid-point of the lumen range. See calculations in file “2017 Lighting Updates and Baseline Estimates”.

EISA exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	Inc/Hal	Baseline LED	Watts _{Ba} <small>se</small>	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2		
						CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90*	CRI >=90	CRI <90	CRI >=90	
			27%	73%										
EISA Exempt	3-Way ⁴⁸⁹	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 1050 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 - 1050 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 ⁴⁹⁰					20.7	9.4				11.3				

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR and CRI<90.

⁴⁸⁹ For 3-way bulbs or fixtures, the product’s median lumens value will be used to determine both LED and baseline wattages.

⁴⁹⁰ Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

Directional Lamps - For Directional R, BR, and ER lamp types:⁴⁹¹

Bulb Type	Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Baseline LED		Watts _{Base}	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		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
		200	299	20	4.2	5.0	3.6	4.1	2.9	3.6	1.4	0.9	2.1	1.4

⁴⁹¹ From pg. 13 of the Energy Star Specification for lamps v2.1.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.4 LED Lamp Specialty

Bulb Type	Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Baseline LED	Watts _{Base}	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
						CRI <90	CRI >=90	CRI <90	CRI >=90	CRI <90*	CRI >=90	CRI <90	CRI >=90
*All reflector lamps below lumen ranges specified above	300	399	30	5.8	7.1	5.0	5.7	4.1	5.0	2.1	1.4	3.0	2.1
Weighted Average, if unknown ⁴⁹²					16.7	12.2				4.5			

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR 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	Baseline LED	Watt _{SBase}	WattsEff ESTAR		WattsEff CEE T2		DeltaWatts ESTAR		DeltaWatts CEE T2	
						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 ⁴⁹³					25.3	12.4				12.9			

*If lumen range is known but Efficiency rating or CRI is unknown assume ESTAR and CRI<90.

⁴⁹² Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

⁴⁹³ Weighted average is based on 2018 and 2019 data provided by MidAmerican and Alliant. Assumes ENERGY STAR CRI<90 for the efficient wattage.

- Hours = Average hours of use per year as provided by the customer or selected from the Lighting Reference Table in Section 3.4. If hours or building type are unknown, use the Nonresidential Average value.
- WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 3.4. for each building type. If unknown, use the Nonresidential Average value.
- ISR = In Service Rate or the percentage of units rebated that get installed.
=100% if application form completed with sign off that equipment is not placed into storage. If sign off form not completed, assume the following:

Program	Discounted In Service Rate (ISR) ⁴⁹⁴
Retail (Time of Sale) ⁴⁹⁵	89%
Direct Install ⁴⁹⁶ and Retrofit	97%

Heating Penalty:

If electrically heated building:⁴⁹⁷

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

- IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

⁴⁹⁴ 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 “Non-Res Lighting ISR calculation_2018.xlsx” for more information.

⁴⁹⁵ The 1st year in service rate for Retail LEDs is a weighted average based on PY7 and PY9 evaluations from ComEd’s, Illinois commercial lighting program (BILD) and PY9 data from Ameren Illinois Instant Incentives program.

⁴⁹⁶ Consistent with CFL assumption. Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys; <http://www.ilsag.info/evaluation-documents.html>

⁴⁹⁷ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * WHFd * CF * ISR$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

CF = Summer Peak Coincidence Factor for measure is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):⁴⁹⁸

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTherms)$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

PEAK GAS SAVINGS

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

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

Where:

ΔTherms = Therm impact calculated above

HeatDays = Heat season days per year
= 190⁴⁹⁹

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-LEDS-V08-240101

SUNSET DATE: 1/1/2025

⁴⁹⁸ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁴⁹⁹ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

3.4.5. LED Fixtures

DESCRIPTION

The installation of Light-Emitting Diode (LED) lighting systems have comparable luminosity to incandescent bulbs and equivalent fluorescent lamps at significantly less wattage, lower heat, and with significantly longer lifetimes.

This measure provides savings assumptions for a variety of efficient lighting fixtures including internal and external LED fixtures, recess (troffer), canopy, and pole fixtures, as well as refrigerator and display case lighting.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, all LED fixtures must fall within the lumen ranges listed in the tables and be ENERGY STAR labeled or on the Design Light Consortium qualifying product list.⁵⁰⁰ All LED fixtures that fall outside the lumen ranges listed in the tables would have to be processed custom. Delamping projects, i.e., those achieving an overall decrease in luminosity, **MUST NOT** use default, tabulated baseline power assumptions, since default values assume luminosity is maintained. For such projects, actual baseline power must be used in savings calculations.

DEFINITION OF BASELINE EQUIPMENT

For TOS and RF installations, the baselines efficiency case is project specific and is determined using actual fixture types and counts from the existing space. The existing fluorescent fixture end connectors and ballasts must be completely removed to qualify.

Where the installation technology is not known, the assumed baselines condition for an outdoor pole/arm, wall-mounted, garage/canopy fixture and high-bay luminaire with a high intensity discharge light source is a metal halide fixture. Deemed fixture wattages are provided in reference tables at the end of this characterization.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated measure life of LED Fixtures is 13 years.⁵⁰¹

DEEMED MEASURE COST

Actual incremental costs should be used if available. For default values, refer to the reference tables below.

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * WHFe * ISR$$

Where:

⁵⁰⁰ DesignLights Consortium Qualified Products List <http://www.designlights.org/qpl>

⁵⁰¹ GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures.

Watts _{Base}	= Input wattage of the existing or baseline system. Reference the “LED New and Baseline Assumptions” table for default values when baseline is unknown.
Watts _{EE}	= Actual wattage of LED fixture purchased / installed. If unknown, use default provided in “LED New and Baseline Assumptions”.
Hours	= Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 3.4. by building type. If hours or building type are unknown, use the Nonresidential Average value.
WHFe	= Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 3.4 for each building type. If building is un-cooled, the value is 1.0.
ISR	= In Service Rate is assumed to be 95% for Time of Sale and 100% for Retrofit. ⁵⁰²

Heating Penalty:

If electrically heated building:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

IFkWh	= Lighting-HVAC Interaction Factor for electric heating impacts; ⁵⁰³ this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.
-------	---

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * WHFd * CF$$

Where:

WHFd	= Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Lighting Reference Table in Section 3.4. for each building type. If the building is not cooled, WHFd is 1.
CF	= Summer Peak Coincidence Factor for measure is selected from the Lighting Reference Table in Section 3.4. for each building type. If the building type is unknown, use the Nonresidential Average value.

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTtherms)$$

Where:

IFTtherms	= Lighting-HVAC Integration Factor for gas heating impacts; ⁵⁰⁴ this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4.
-----------	---

⁵⁰² Negotiated value during Iowa TRM Technical Advisory Committee call, 08/25/2015.

⁵⁰³ Negative value because this is an increase in heating consumption due to the efficient lighting.

⁵⁰⁴ Negative value because this is an increase in heating consumption due to the efficient lighting.

If unknown, use the Nonresidential Average value.

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
- = 190⁵⁰⁵

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See Reference Tables below for default assumptions.

REFERENCE TABLES⁵⁰⁶

LED Category	EE Measure		Baseline			Incremental Cost	Mid-life Savings Adjustment (2022)
	Description	Watts _{EE}	Description	Watts _{BASE}	Base Cost		
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	17.6	40% CFL 26W Pin Based & 60% PAR30/38	54.3	\$15	\$27	N/A
LED Interior Directional	LED Track Lighting	12.2	10% CMH PAR38 & 90% Halogen PAR38	60.4	\$25	\$59	N/A
	LED Wall-Wash Fixtures	8.3	40% CFL 42W Pin Base & 60% Halogen PAR38	17.7	\$25	\$59	N/A
LED Display Case	LED Display Case Light Fixture	4.0 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	\$10/ft	\$11/ft	N/A
	LED Undercabinet Shelf-Mounted Task Light Fixtures	4.0 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	\$10/ft	\$11/ft	N/A
	LED Refrigerated Case Light, Horizontal or Vertical	4.0 / ft	5'T8	15.2 / ft	\$10/ft	\$11/ft	N/A
	LED Freezer Case Light, Horizontal or Vertical	4.0 / ft	6'T12HO	18.7 / ft	\$10/ft	\$11/ft	N/A
LED Linear	T8 LED Replacement Lamp	8.9	F17T8 Standard Lamp - 2	15.0	\$5.00	\$12.75	N/A

⁵⁰⁵ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

⁵⁰⁶ Watt, lumen, and costs data assumptions for efficient measures are based upon Design Light Consortium Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. See "LED Lighting Systems TRM Reference Tables 2022 Iowa.xlsx" for more information and specific product links.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure		Baseline			Incremental Cost	Mid-life Savings Adjustment (2022)
	Description	Watts _{EE}	Description	Watts _{BASE}	Base Cost		
Replacement Lamps	(TLED), < 1200 lumens		foot				
	T8 LED Replacement Lamp (TLED), 1200-2400 lumens	15.8	F32T8 Standard Lamp - 4 foot	28.2	\$3.00	\$15	N/A
	T8 LED Replacement Lamp (TLED), 2401-4000 lumens	22.9	F32T8/HO Standard Lamp - 4 foot	42	\$11.00	\$13.25	N/A
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	25.4	2-Lamp 32w T8 (BF < 0.89)	57.0	\$50	\$53	97%
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	36.7	3-Lamp 32w T8 (BF < 0.88)	84.5	\$55	\$69	92%
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	33.3	2-Lamp 32w T8 (BF < 0.89)	57.0	\$50	\$55	96%
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	44.8	3-Lamp 32w T8 (BF < 0.88)	84.5	\$55	\$76	90%
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	57.2	4-Lamp 32w T8 (BF < 0.88)	112.6	\$60	\$104	91%
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	21.8	1-Lamp 32w T8 (BF < 0.91)	29.1	\$50	\$22	96%
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	33.7	2-Lamp 32w T8 (BF < 0.89)	57.0	\$55	\$75	96%
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	43.3	3-Lamp 32w T8 (BF < 0.88)	84.5	\$60	\$83	91%
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	19.5	1-Lamp 32w T8 (BF < 0.91)	29.1	\$50	\$10	97%
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	32.1	2-Lamp 32w T8 (BF < 0.89)	57.0	\$55	\$52	96%
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	43.5	3-Lamp 32w T8 (BF < 0.88)	84.5	\$60	\$78	91%
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	56.3	T5HO 2L-F54T5HO - 4'	120.0	\$65	\$131	N/A
	LED Surface & Suspended Linear Fixture, >7500 lumens	82.8	T5HO 3L-F54T5HO - 4'	180.0	\$70	\$173	N/A
LED High & Low Bay Fixtures	LED Low-Bay or High-Bay Fixtures, ≤ 10,000 lumens	61.6	3-Lamp T8HO Low-Bay	157.0	\$75	\$44	N/A
	LED High-Bay Fixtures, 10,001-15,000 lumens	99.5	4-Lamp T8HO High-Bay	196.0	\$100	\$137	N/A
	LED High-Bay Fixtures, 15,001-20,000 lumens	140.2	6-Lamp T8HO High-Bay	294.0	\$125	\$202	N/A
	LED High-Bay Fixtures, > 20,000 lumens	193.8	8-Lamp T8HO High-Bay	392.0	\$150	\$264	N/A
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	12.9	25% 73 Watt EISA Inc, 75% 1L T8	42.0	\$20	\$18	N/A
	LED Ag Interior Fixtures, 2,001-4,000 lumens	29.7	25% 146 Watt EISA Inc, 75% 2L T8	81.0	\$40	\$48	N/A

LED Category	EE Measure		Baseline			Incremental Cost	Mid-life Savings Adjustment (2022)
	Description	Watts _{EE}	Description	Watts _{BASE}	Base Cost		
LED Ag Interior Fixtures	LED Ag Interior Fixtures, 4,001-6,000 lumens	45.1	25% 217 Watt EISA Inc, 75% 3L T8	121.0	\$60	\$57	N/A
	LED Ag Interior Fixtures, 6,001-8,000 lumens	59.7	25% 292 Watt EISA Inc, 75% 4L T8	159.0	\$80	\$88	N/A
	LED Ag Interior Fixtures, 8,001-12,000 lumens	84.9	200W Pulse Start Metal Halide	227.3	\$120	\$168	N/A
	LED Ag Interior Fixtures, 12,001-16,000 lumens	113.9	320W Pulse Start Metal Halide	363.6	\$160	\$151	N/A
	LED Ag Interior Fixtures, 16,001-20,000 lumens	143.7	350W Pulse Start Metal Halide	397.7	\$200	\$205	N/A
	LED Ag Interior Fixtures, > 20,000 lumens	193.8	(2) 320W Pulse Start Metal Halide	727.3	\$240	\$356	N/A
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	34.1	100W Metal Halide	113.6	\$60	\$80	N/A
	LED Exterior Fixtures, 5,001-10,000 lumens	67.2	175W Pulse Start Metal Halide	198.9	\$90	\$248	N/A
	LED Exterior Fixtures, 10,001-15,000 lumens	108.8	250W Pulse Start Metal Halide	284.1	\$120	\$566	N/A
	LED Exterior Fixtures, >15,000 lumens	183.9	400W Pulse Start Metal Halide	454.5	\$150	\$946	N/A

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	50,000	\$30.75	70,000	\$47.50	2,500	\$8.86	40,000	\$14.40
LED Interior Directional	LED Track Lighting	50,000	\$39.00	70,000	\$47.50	2,500	\$12.71	40,000	\$11.00
	LED Wall-Wash Fixtures	50,000	\$39.00	70,000	\$47.50	2,500	\$9.17	40,000	\$27.00
LED Display Case	LED Display Case Light Fixture	50,000	\$9.75/ft	70,000	\$11.88/ft	2,500	\$6.70	40,000	\$5.63
	LED Undercabinet Shelf-Mounted Task Light Fixtures	50,000	\$9.75/ft	70,000	\$11.88/ft	2,500	\$6.70	40,000	\$5.63
	LED Refrigerated Case Light, Horizontal or Vertical	50,000	\$8.63/ft	70,000	\$9.50/ft	15,000	\$1.13	40,000	\$8.00
	LED Freezer Case Light, Horizontal or Vertical	50,000	\$7.88/ft	70,000	\$7.92/ft	12,000	\$0.94	40,000	\$6.67
LED Linear Replacement Lamps	T8 LED Replacement Lamp (TLED), < 1200 lumens	50,000	\$8.57	70,000	\$13.67	24,000	\$6.17	40,000	\$11.96
	T8 LED Replacement Lamp (TLED), 1200-2400 lumens	50,000	\$8.57	70,000	\$13.67	24,000	\$6.17	40,000	\$11.96

Iowa Energy Efficiency Statewide Technical Reference Manual –3.4.5 LED Fixtures

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
	T8 LED Replacement Lamp (TLED), 2401-4000 lumens	50,000	\$5.76	70,000	\$13.67	24,000	\$6.17	40,000	\$11.96
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	50,000	\$78.07	70,000	\$40.00	24,000	\$26.33	40,000	\$35.00
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	50,000	\$89.23	70,000	\$40.00	24,000	\$39.50	40,000	\$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	50,000	\$96.10	70,000	\$40.00	24,000	\$12.33	40,000	\$35.00
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	50,000	\$114.37	70,000	\$40.00	24,000	\$18.50	40,000	\$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	50,000	\$137.43	70,000	\$40.00	24,000	\$24.67	40,000	\$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	50,000	\$65.43	70,000	\$40.00	24,000	\$6.17	40,000	\$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	50,000	\$100.44	70,000	\$40.00	24,000	\$12.33	40,000	\$35.00
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	50,000	\$108.28	70,000	\$40.00	24,000	\$18.50	40,000	\$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	50,000	\$62.21	70,000	\$40.00	24,000	\$6.17	40,000	\$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	50,000	\$93.22	70,000	\$40.00	24,000	\$12.33	40,000	\$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	50,000	\$114.06	70,000	\$40.00	24,000	\$18.50	40,000	\$35.00
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	50,000	\$152.32	70,000	\$40.00	30,000	\$26.33	40,000	\$60.00
	LED Surface & Suspended Linear Fixture, >7500 lumens	50,000	\$183.78	70,000	\$40.00	30,000	\$39.50	40,000	\$60.00
LED High & Low Bay Fixtures	LED Low-Bay or High-Bay Fixtures, ≤ 10,000 lumens	50,000	\$112.13	70,000	\$62.50	18,000	\$64.50	40,000	\$92.50
	LED High-Bay Fixtures, 10,001-15,000 lumens	50,000	\$186.93	70,000	\$62.50	18,000	\$86.00	40,000	\$92.50
	LED High-Bay Fixtures,	50,000	\$243.06	70,000	\$62.50	18,000	\$129.00	40,000	\$117.50

LED Category	EE Measure Description	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replace Cost	LED Driver Life (hrs)	Total LED Driver Replace Cost	Lamp Life (hrs)	Total Lamp Replace Cost	Ballast Life (hrs)	Total Ballast Replace Cost
	15,001-20,000 lumens								
	LED High-Bay Fixtures, >20,000 lumens	50,000	\$297.87	70,000	\$62.50	18,000	\$172.00	40,000	\$142.50
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	50,000	\$41.20	70,000	\$40.00	1,000	\$1.23	40,000	\$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	50,000	\$65.97	70,000	\$40.00	1,000	\$1.43	40,000	\$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	50,000	\$80.08	70,000	\$40.00	1,000	\$1.62	40,000	\$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	50,000	\$105.54	70,000	\$40.00	1,000	\$1.81	40,000	\$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	50,000	\$179.81	70,000	\$62.50	15,000	\$63.00	40,000	\$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	50,000	\$190.86	70,000	\$62.50	15,000	\$68.00	40,000	\$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	50,000	\$237.71	70,000	\$62.50	15,000	\$73.00	40,000	\$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	50,000	\$331.73	70,000	\$62.50	15,000	\$136.00	40,000	\$202.50
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	50,000	\$73.80	70,000	\$62.50	15,000	\$58.00	40,000	\$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	\$124.89	70,000	\$62.50	15,000	\$63.00	40,000	\$112.50
	LED Exterior Fixtures, 10,001-15,000 lumens	50,000	\$214.95	70,000	\$62.50	15,000	\$68.00	40,000	\$122.50
	LED Exterior Fixtures, > 15,000 lumens	50,000	\$321.06	70,000	\$62.50	15,000	\$73.00	40,000	\$132.50

MEASURE CODE: NR-LTG-LDFX-V07-240101

SUNSET DATE: 1/1/2025

3.4.6. T5 HO Fixtures and Lamp/Ballast Systems

DESCRIPTION

T5 HO lamp/ballast systems have greater lumens per watt than a typical T8 system. The smaller lamp diameter of the T5HO also increases optical control efficiency, and allows for more precise control and directional distribution of lighting. These characteristics make it easier to design light fixtures that can produce equal or greater light than standard T8 or T12 systems, while using fewer watts. In addition, when lighting designers specify T5 HO lamps/ballasts, they can use fewer luminaires per project, especially for large commercial projects, thus increasing energy savings further.⁵⁰⁷

The main markets served by T5 HO fixtures and lamps include retrofit in the commercial and nonresidential sector, specifically industrial, warehouse, and grocery facilities with higher ceiling heights that require maximum light output.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The definition of the efficient equipment is T5 HO high-bay (>15ft mounting height) fixtures with 3, 4, 6, or 8-lamp configurations.

DEFINITION OF BASELINE EQUIPMENT

The definition of baseline equipment varies based on number of lamps in a fixture and is defined in the baseline reference table at the end of this characterization.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of the efficient equipment fixture is 15 years.⁵⁰⁸

DEEMED MEASURE COST

The deemed measure cost is found in reference table at the end of this characterization.

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * WHFe * ISR$$

Where:

Watts_{Base} = Input wattage of the baseline system is dependant on new fixture configuration and

⁵⁰⁷ Lighting Research Center. T5 Fluorescent Systems.

<http://www.lrc.rpi.edu/programs/nlpi/lightingAnswers/lat5/abstract.asp>

⁵⁰⁸ Focus on Energy Evaluation “Business Programs: Measure Life Study” Final Report, August 9, 2009 prepared by PA Consulting Group.

found in the ‘T5HO Efficient and Baseline Wattage and Cost Assumptions’ reference table below.

- Watts_{EE} = Input wattage depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the ‘T5HO Efficient and Baseline Wattage and Cost Assumptions’ reference table below.
- Hours = Average annual lighting hours of use as provided by the customer or selected from the Lighting Reference Table in Section 3.4 as annual operating hours, by building type. If hours or building type are unknown, use the Nonresidential Average value.
- WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Lighting Reference Table in Section 3.4 for each building type. If building is un-cooled, the value is 1.0.
- ISR = In Service Rate or the percentage of units rebated that get installed.
=100% if application form completed with sign off that equipment is not placed into storage. If sign off form not completed, assume 98%.⁵⁰⁹

Heating Penalty:

If electrically heated building:⁵¹⁰

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

Where:

- IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

SUMMER COINCIDENT DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * WHFd * CF$$

Where:

- WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Lighting Reference Table in Section 3.4 for each building type. If the building is not cooled, WHFd is 1.
- CF = Summer Peak Coincidence Factor for measure is selected from the Lighting Reference Table in Section 3.4 for each building type. If the building type is unknown, use the Nonresidential Average value.

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTherms)$$

Where:

- IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the

⁵⁰⁹ Based upon review of PY5-6 evaluations from ComEd, IL commercial lighting program (BILD)

⁵¹⁰ Negative value because this is an increase in heating consumption due to the efficient lighting.

increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4.⁵¹¹ If unknown, use the Nonresidential Average value.

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
= 190⁵¹²

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See reference tables for different cost assumptions for lamps and ballasts. When available, actual costs and hours of use should be used.

REFERENCE TABLES

T5HO Efficient and Baseline Wattage And Cost Assumptions⁵¹³

EE Measure Description	WattsEE	Baseline Description	WattsBASE	Incremental Cost
3-Lamp T5 High-Bay	176	200 Watt Pulse Start Metal-Halide	227	\$100.00
4-Lamp T5 High-Bay	235	320 Watt Pulse Start Metal-Halide	364	\$100.00
6-Lamp T5 High-Bay	352	400 Watt Pulse Start Metal-Halide	455	\$100.00
8-Lamp T5 High-Bay	470	750 Watt Pulse Start Metal-Halide	825	\$100.00

T5 HO Component Costs and Lifetimes⁵¹⁴

EE Measure Description	EE Measure				Baseline			
	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost	Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
3-Lamp T5 High-Bay	30,000	\$63.00	70,000	\$87.50	15,000	\$63.00	40,000	\$107.50
4-Lamp T5 High-Bay	30,000	\$84.00	70,000	\$87.50	20,000	\$68.00	40,000	\$117.50
6-Lamp T5 High-Bay	30,000	\$126.00	70,000	\$112.50	20,000	\$73.00	40,000	\$127.50
8-Lamp T5 High-Bay	30,000	\$168.00	70,000	\$137.50	20,000	\$78.00	40,000	\$137.50

MEASURE CODE: NR-LTG-T5HO-V03-240101

⁵¹¹ Negative value because this is an increase in heating consumption due to the efficient lighting.
⁵¹² Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).
⁵¹³ Reference Table adapted from Efficiency Vermont TRM, T5 Measure Savings Algorithms and Cost Assumptions, October, 2014. Refer to “Updated-T5HO-adjusted deemed costs.baselines-7-30-15.xlsx” for more information.
⁵¹⁴ Costs include labor cost – see “Updated-T5HO-adjusted deemed costs.baselines-7-30-15.xlsx” for more information.

SUNSET DATE: 1/1/2025

3.4.7. High Performance and Reduced Wattage T8 Fixtures and Lamps (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.

3.4.8. Metal Halide (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.

3.4.9. Commercial LED Exit Sign

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent/compact fluorescent (CFL) exit sign in a Commercial 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.⁵¹⁵ 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: Retrofit (RF), and Direct Install (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.⁵¹⁶

DEFINITION OF BASELINE EQUIPMENT

The baseline is the existing fluorescent/compact fluorescent (CFL) exit sign.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 13 years.⁵¹⁷

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 at \$32.50.⁵¹⁸

LOADSHAPE

Loadshape E01 – Flat

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS ⁵¹⁹

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * WHFe$$

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following:

⁵¹⁵ ENERGY STAR “Save Energy, Money and Prevent Pollution with LED Exit Signs”

⁵¹⁶ 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.

⁵¹⁷ GDA Associates Inc. “Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures”, June 2007.

⁵¹⁸ Price includes new exit sign/fixture and installation. LED exit cost cost/unit is \$22.50 from the NYSERDA Deemed Savings Database and assuming IA labor cost of 15 minutes @ \$40/hr.

⁵¹⁹ 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).

Program Type	Baseline Type	Watts _{Base}
Retrofit/Direct Install ⁵²⁰	CFL (dual sided)	14W ⁵²¹
	CFL (single sided)	7W

Watts_{EE} = Actual wattage if known, if unknown assume singled sided 2W and dual sided 4W⁵²²

Hours = Annual operating hours
= 8760

WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Lighting Reference Table 3.4. If unknown, use the Nonresidential Average value.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

$$\begin{aligned} \Delta kWh &= ((14 - 4) / 1000) * 8,766 * 1.13 \\ &= 99.1 \text{ kWh} \end{aligned}$$

HEATING PENALTY

If electrically heated building:⁵²³

$$\Delta kWh_{\text{heatpenalty}} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

$$\begin{aligned} \Delta kWh_{\text{heatingpenalty}} &= ((14 - 4) / 1000) * 8,766 * (-0.43) \\ &= -37.7 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * WHF_d * CF$$

Where:

⁵²⁰ Federal Standards effectively ended the manufacturing of incandescent exit signs in 2006 and therefore in unknown instances it should be assumed existing exit signs use CFL lamps since the lifetime of any remaining incandescent exit signs would have expired per the 13 year measure assigned to this measure.

⁵²¹ Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: <http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf>

⁵²² Average Exit LED watts are assumed as a 2W as listed in Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: <http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf>

⁵²² Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages. Available at: <http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf>

⁵²³ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

CF = Summer Peak Coincidence Factor for this measure
= 1-00%⁵²⁴

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in electrically heated building with cooling:

$$\begin{aligned} \Delta kW &= ((14 - 4) / 1000) * 1.42 * 1.0 \\ &= 0.0142 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated buiding (or if heating is unknown):⁵²⁵

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * (- IFTherms)$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential average value.

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in a fossil fuel heated building:

$$\begin{aligned} \Delta Therms &= ((14 - 4) / 1000) * 8,766 * (-0.018) \\ &= -1.5779 \text{ therms} \end{aligned}$$

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:

ΔTherms = Therm impact calculated above
HeatDays = Heat season days per year
= 190⁵²⁶

For example, for a 4W, dual sided LED exit sign replacing a CFL lamp in a fossil fuel heated building:

$$\begin{aligned} \Delta PeakTherms &= -1.5779/190 \\ &= -0.0083 \text{ therms} \end{aligned}$$

⁵²⁴ Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

⁵²⁵ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁵²⁶ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

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	CFL lamp	\$13.00 ⁵²⁷	0.57 years ⁵²⁸

MEASURE CODE: NR-LTG-EXIT-V05-240101

SUNSET DATE: 1/1/2027

⁵²⁷ Consistent with assumption as listed by the U.S. Department of Energy, ENERGY STAR Life Cycle Cost Exit-Sign Calculator available at https://www.energystar.gov/index.cfm?c=exit_signs.pr_exit_signs for estimated labor cost of \$10 (assuming \$40/hour and a task time of 15 minutes). Replacement of a CFL bulb is assumed to be \$3 as noted by regional IA program details (IPL Business Assessment).

⁵²⁸ 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.

3.4.10. LED Street Lighting

This measure characterizes the savings associated with LED street lighting conversions where a Light Emitting Diode (LED) fixture replaces a Metal Halide, High Pressure Sodium or Mercury Vapor outdoor lighting system. LED street lights provide considerable benefits compared to HID lights including:

- Improved nighttime visibility and safety through better color rendering, more uniform light distribution and elimination of dark areas between poles.
- Reduced direct and reflected uplight which are the primary causes of urban sky glow.
- 40-80% energy savings (dependent on incumbent lighting source).
- 50-75% street lighting maintenance savings.⁵²⁹

This measure includes LED fixture housings including cobrahead and post-top and is applicable only where utility tariffs support LED street lighting conversions.

This measure was developed to be applicable for a one-to-one Retrofit (RF) opportunity only.⁵³⁰

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment must be an LED fixture that meets the United Illuminating Rate Schedule, alongside all other luminary performance requirements based on site characteristics⁵³¹ and all local, state, and federal codes.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the existing system – a Metal Halide, High Pressure Sodium or Mercury Vapor outdoor lamp, ballast and fixture.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 20 years.⁵³²

DEEMED MEASURE COST⁵³³

Actual measure installation cost should be used (including material and labor).⁵³⁴ Use actual costs of LED unit when know. If unknown use the default values/luminaire provided below:

⁵²⁹ See NEEP “LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic”, January 2015, and the Municipal Solid State Street Lighting Consortium for more information
<http://www1.eere.energy.gov/buildings/ssl/consortium.html>

⁵³⁰ Many light fixtures were placed in service 20-50 years ago and may no longer service their intended purpose. It is important to conduct a comprehensive assessment of lighting needs with a lighting professional when considering a LED street lighting project. LED street lighting can result in removal of lighting all together as LED lights provide better CRI and lighting levels than existing HID lighting types. While this measure only characterizes a one-to-one replacement value it is recommended that this measure be updated following an IA assessment to see where LED street lighting has resulted in the removal of street lighting to ensure additional savings calculations are captured. Recommend using Street and Parking Facility Lighting Retrofit Financial Analysis Tool developed by DOE Municipal Solid-State Street Lighting Consortium and the Federal Energy Management Program.

⁵³¹ See DOE Municipal Solid-State Street Lighting Consortium “Model specifications for LED roadway luminaires v.2.0”
<http://energy.gov/eere/ssl/downloads/model-specification-led-roadway-luminaires-v20>

⁵³² It is widely assumed that LEDs used in street lighting available today may still be producing over 80% of their initial light after 100,000 hours. See the DOE Municipal Solid-State Street Lighting Consortium for more information.

<http://www1.eere.energy.gov/buildings/ssl/consortium.html>

⁵³³ NEEP DOE LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic" - based upon their reference of Reuters. “Cree Introduces the Industry’s First \$99 LED Street Light as a Direct Replacement for Residential Street Lights,” (August 2013).

⁵³⁴ Labor should include the removal of the old fixture and installation of the new fixture. IA DOT prevailing wage should be assumed.

Light output						
	Low (<50W)		Med (50W-100W)		High (>100W)	
Fixture Type	min	max	min	max	min	max
Decorative/Post Top	\$350.00	\$615.00	\$550.00	\$950.00	\$750.00	\$1,450.00
Cobrahead	\$99.00	\$225.00	\$179.00	\$451.00	\$310.00	\$720.00

LOADSHAPE

Loadshape NREL017 – Nonresidential Street Lighting

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS⁵³⁵

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours$$

Where:

Watts_{Base} = Actual wattage if known, if unknown assume the following nominal wattage based on technology.

Metal Halide = 250W⁵³⁶

Mercury Vapor = 175W⁵³⁷

High Pressure Sodium = 170W⁵³⁸

SUMMER COINCIDENT PEAK DEMAND SAVINGS⁵³⁹

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * CF$$

CF = Summer Peak Coincidence Factor for this measure

=0%

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

⁵³⁵ There is no ISR calculation. Savings are per unit.

⁵³⁶ Based on averaging Metal Halide information provided in IA custom LED street lighting installations with MH baseline and NEEP Street Lighting Assessment (100, 175, 250, 400W)

⁵³⁷ Based on averaging Mercury Vapor information provided in IA custom LED street lighting installations and NEEP Street Lighting Assessment (175W)

⁵³⁸ Based on averaging High Pressure Sodium information provided in IA custom LED street lighting installations and NEEP Street Lighting Assessment (50, 70, 100, 150, 250, 400).

⁵³⁹ On-peak savings for street lighting occur mostly in the winter. Only off-peak demand savings occur during the summer months.

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M costs are estimated at \$50/LED luminaire annually.⁵⁴⁰

MEASURE CODE: NR-LTG-STLT-V01-190101

SUNSET DATE: 1/1/2027

⁵⁴⁰ Based upon NEEPs report and quantitative analysis of LED street light conversions in the Northeast and Mid-Atlantic region. municipal luminaires evaluated by “LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic”, January 2015.

3.4.11. LED Traffic and Pedestrian Signals (Removed 2021)

This measure was archived since the federal code has required LEDs for all traffic and pedestrian modules manufactured since January 2006. No utility is continuing to offering this measure as a retrofit. Please refer to Iowa Energy Efficiency Statewide Technical Reference Manual Version 5.0 Volume 3: Nonresidential Measures; Final: July 15, 2020; Effective January 1, 2021 in which the measure was last active.

3.4.12. Lighting Controls

DESCRIPTION

Occupancy sensors are devices that reduce lighting levels by turning lights on or off in response to the presence (or absence) of people in a defined area. Associated energy savings depends on the building type, location area covered, type of lighting and activity, and occupancy pattern.

Daylight sensor lighting controls are devices that reduce lumen output levels in response to the amount of daylight available in an area. Such systems save energy by either shutting off lights completely or dimming when there is adequate natural light available.

High end trim refers to the setting of a maximum lumen output for fixtures within a zone to reduce demand below the full rated fixture wattage.

As per the DesignLights Consortium (DLC) definition, Networked Lighting Controls requires systems to have “fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling and cybersecurity. The network ability allows building managers to group lights with specific zonal control and scheduling strategies, energy monitoring and high_end trim resulting in a higher savings capability.”

Luminaire Level Lighting Controls (LLLCs) have individual sensors and control logic on each fixture allowing further refinement and savings opportunities.

This measure relates to the installation of interior occupancy sensors, daylighting or high end trim controls on an existing lighting system (not replacement). Lighting control types covered by this measure include switch-mounted, remote-mounted, fixture-mounted, integrated in addition to more sophisticated networked lighting capabilities. Daylight sensors covered by this measure include “on or off”, stepped dimming systems, such as dual ballast (high/low HID⁵⁴¹ or inboard/outboard), and continuous dimming systems based on light levels from available daylight.

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

DEFINITION OF EFFICIENT EQUIPMENT

It is assumed that this measure characterization applies to only those lighting controls that regulate a minimum average wattage greater than 45W per control for switch, fixture and remote mounted occupancy sensors, and 20W for integrated sensors. If applicable, it must be accompanied by a daylight harvesting ballast system that meets current CEE specifications at full light output.⁵⁴² This measure includes both hard-wired and wireless controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency case assumes lighting fixtures with neither occupancy controls nor daylight control sensor. Also, lighting is operated at normal powers levels and controlled with a manual switch.

Note that in new construction or in areas receiving major rehab (additions, alterations renovations, or repairs), occupancy sensors are required by IECC 2012 (section C405.2.2.2) to be installed in the following locations; classrooms, conference/meeting rooms, employee lunch and break rooms, private offices, restrooms, storage rooms and janitorial closets, and other spaces 300 ft² or less enclosed by floor to ceiling height partitions. Savings should therefore not be claimed for occupancy sensors installed in these instances.

⁵⁴¹ Uniformed Methods Project: *Methods for Determining Energy Efficiency Savings for Specific Measures: Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol*, NREL, April 2013. Such HID fixtures typically have only one lamp that can be operated at two different output levels by a two stage ballast; this differs from stepped dimming systems that dim by controlling lamps powered by a single ballast.

⁵⁴² Visit <http://library.cee1.org/content/commercial-lighting-qualifying-products-lists>

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for Luminaire-level lighting controls (LLLCs) / Networked Lighting Controls (NLC) is assumed to be 15 years, consistent with the average expected lifetime of the fixture. The expected measure life for all lighting controls is assumed to be 8 years.⁵⁴³

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

Lighting Control Type	Cost ⁵⁴⁴
Switch-Mounted (Wall) Occupancy Sensor	\$54
Fixture-Mounted Occupancy Sensor	\$67
Remote-Mounted (Ceiling) Occupancy Sensor	\$105
Fixture-Mounted Daylight Sensor	\$50
Remote-Mounted Daylight Sensor	\$65
Integrated Occupancy Sensor	\$40
Integrated Dual Occupancy & Daylight Sensor	\$50
Fixture-Mounted Dual Occupancy & Daylight Sensor	\$100
Remote-Mounted Dual Occupancy & Daylight Sensor	\$125
Luminaire-Level Lighting Controls	\$56
Interior Networked Lighting Controls <10,000 sqft building	\$0.86 per ft ²
Interior Networked Lighting Controls 10,000-100,000 sqft building	\$0.59 per ft ²
Interior Networked Lighting Controls >100,000 sqft building	\$0.40 per ft ²
High End Trim	\$0.06 per ft ²

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS⁵⁴⁵

$$\Delta kWh = kW_{Controlled} * Hours * (ESF_{EE} - ESF_{Base}) * WHFe$$

Where:

$kW_{Controlled}$ = Total lighting load connected to the control in kilowatts. The total connected load per control

⁵⁴³ See file “DEER2014-EUL-table-update_2014-02-05.xlsx” or <http://www.deeresources.com/>

⁵⁴⁴ Based on averaging typical prices quoted by online vendors. See 'Lighting Control Analysis_2020.xlsx'; “Cost” Sheet for more information. Cost assumption for Luminaire Level Lighting Controls is based on the average of ‘clever’ and ‘clever-hybrid’ LLLC incremental costs, including a per fixture contribution to the necessary gateway, servers and installation labor from Kisch et al, “2020 Luminaire Level Lighting Controls Incremental Cost Study”, Energy Solutions on behalf of NEEA, January 2021. Cost assumptions for Interior Networked Lighting Controls is based on the average of “office”, “warehouse”, and “retail” by building size from Schwartz et al., “The Value Proposition for Cost-Effective, Demand Responsive-Enabling Nonresidential Lighting System Retrofits in California Buildings”, Lawrence Berkeley National Laboratory and Energy Solutions prepared for California Energy Commission, April 2019. This includes both material and labor cost estimates.

⁵⁴⁵ It is assumed an ISR of 100%

should be collected from the customer if possible, particularly for networked lighting controls where variance can be significant. Default values are presented below.

Lighting Control Type	Default kW controlled ⁵⁴⁶	Per
Switch (Wall) Mounted Occupancy Sensor	0.254	Control
Fixture-Mounted Occupancy Sensor	0.264	Fixture
Remote (Ceiling) Mounted Occupancy Sensor	0.413	Control
Fixture-Mounted Daylight Sensor	0.095	Fixture
Remote-Mounted Daylight Sensor	0.239	Control
Integrated Occupancy Sensor for LED Interior Fixtures < 10,000 Lumens	0.031	Fixture
Integrated Occupancy Sensor for LED Interior Fixtures ≥ 10,000 Lumens	0.118	Fixture
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	0.031	Fixture
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures ≥ 10,000 Lumens	0.118	Fixture
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	0.031	Fixture
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures ≥ 10,000 Lumens	0.118	Fixture
Remote-Mounted Dual Occupancy & Daylight Sensor	0.239	Control
Luminaire-Level Lighting Controls < 10,000 Lumens	0.031	Fixture
Luminaire-Level Lighting Controls ≥ 10,000 Lumens	0.118	Fixture
Networked Lighting Controls	0.00061	ft ² space controlled

Hours = The total annual operating hours of lighting for each type of building before lighting controls. This number should be collected from the customer. If no data is available, the deemed average number of operating hours, by building type, should be used, as provided by Lighting Reference Table in Section 3.4. If building type is unknown, use the Nonresidential Average value.

ESF_{EE} = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system). Determined on a site-specific basis where possible or using a default energy saving factor presented below:

⁵⁴⁶ Occupancy Sensor controlled kw is based on Alliant Data from program years 2018-2019. Removed 2 outlying data points as well as the Agricultural sector. See 'Lighting Control Analysis_2020.xlsx'; "Wattage_Alliant Data" sheet for details on calculations. For the raw data, please see file 'Alliant Data_Occ Sensors and Daylighting Controls 2018-2019.xlsx'. Integrated Dual and Daylight Sensors controlled kw is based on Efficiency Vermont data from program year 2017 for lighting controls. See 'Lighting Control Analysis_2020.xls'; "Wattage_EVT Data" sheet for details on calculations.

Lighting Control Type	Energy Savings Factor ⁵⁴⁷
Occupancy Sensor (Switch, Wall, Fixture or Remote Mounted or Integrated in Fixture)	24% 37% with High End Trim
Daylight Sensor (Wall, Fixture or Remote Mounted)	28% 41% with High End Trim
Dual Occupancy & Daylight Sensor without verified daylighting savings (Integrated of Fixture Mounted)	24% 37% with High End Trim
Dual Occupancy & Daylight Sensor with verified daylighting savings (Integrated of Fixture Mounted)	38% 51% with High End Trim ⁵⁴⁸
Networked Luminaire-Level Lighting Controls	61% ⁵⁴⁹
Interior Networked Lighting Controls Only with No LLLCs	35%
Interior Networked Lighting Controls (unknown or mixed LLLCs)	49%

ESF_{Base} = Energy Savings Factor of the lighting controls that existed before the new lighting controls were installed. If no prior lighting controls or unknown, assume 0.

WHF_e = Waste heat factor for energy to account for cooling energy savings from more efficient lighting is provided in the Lighting Reference Table in Section 3.4.

Heating Penalty:

If electrically heated building:⁵⁵⁰

$$\Delta kWh_{heatpenalty} = kW_{Controlled} * Hours * (ESF_{EE} - ESF_{Base}) * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the

⁵⁴⁷ Interior controls % savings based except where noted on LBNL, Williams et al, "Lighting Controls in Commercial Buildings", 2012, p172. ESF for Vacancy Sensors is based on Papamichael, Konstantions, Bi-Level Switching in Office Spaces, California Lighting Technology Center, February 1,2010. See Figure 8 on page 10 for relevant study results. The study shows a 30% extra savings above a typical occupancy sensor; 24% * 1.3 = 31%.

ESF for Luminaire Level Lighting Controls, Networked Lighting Controls and the 13% High End Trim adder are based upon the weighted average of results from:

- Pacific Northwest National Laboratory, "Evaluation of Advanced Lighting Control Systems in a Working Office Environment", November 2018.
- Schuetter et al., "Cree SmartCast Lighting Retrofit Demonstration: LED Fixtures and Controls for Advanced Holistic Lighting Solutions", September 2020 (expected).
- DesignLights Consortium and NEEA, "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC" Energy Solutions, September 2020. LLLC ESF used in weighted average is the average of all 98 sites with NLCs w/LLLC. NLC ESF is the average of all 194 buildings. High-end trim adder used for other lighting control types is based on the results for the 96 sites w NLCs w/o LLLC and using the "Other Control Strategies" savings where the baseline had influences from high-end trim removed.

⁵⁴⁸ The ESF_{EE} for interior dual occupancy & daylight sensor with high-end trim is estimated to be higher than the interior networked lighting control ESF_{EE} since this measure requires that the sensors be integrated or fixture mounted which has been documented to lead to higher savings than zone or wall sensors. The NLC measure is not specific to fixture, zone, or wall sensors.

⁵⁴⁹ The ESF_{EE} for LLLC is not separated out based on the inclusion of high-end trim since the DesignLights Consortium Technical Requirements Version NLC5 (1/25/21) requires that high-end trim is included for all interior networked lighting controls including LLLC.

⁵⁵⁰Negative value because this is an increase in heating consumption due to the efficient lighting.

increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table 3.4.

For example, for a Switch (Wall) Mounted Occupancy Sensor:

$$\begin{aligned} \Delta kWh &= 0.254 * 3,065 * 0.24 * 1.06 \\ &= 198.1 \text{ kWh} \end{aligned}$$

For a switch (wall) mounted occupancy sensor installed in a building with electric resistance heating, the electric heating penalty is:

$$\begin{aligned} \Delta kWh_{\text{heating penalty}} &= 0.254 * 3,065 * 0.24 * (-0.24) \\ &= -44.8 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kW_{\text{Controlled}} * WHF_d * (CF_{\text{baseline}} - CF_{LC})$$

Where:

WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table in Section 3.4

CF_{baseline} = Baseline Summer Peak Coincidence Factor for the lighting system without Occupancy Sensors installed is selected from the Lighting Reference Table in Section 3.4 for each building type. If the building type is unknown, use the Nonresidential Average value.

CF_{LC} = Summer Peak Coincidence Factor the lighting system with Lighting Controls installed is 15% regardless of building type.⁵⁵¹

For example, for a Switch (Wall) Mounted Occupancy Sensor:

$$\begin{aligned} \Delta kW &= 0.254 * 1.28 * (0.6907 - 0.15) \\ &= 0.1758 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

If gas heated building (or unknown):

$$\Delta Therms = kW_{\text{Controlled}} * Hours * (ESF_{EE} - ESF_{Base}) * -IF_{Therms}$$

Where:

IF_{Therms} = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and is provided in the Lighting Reference Table in Section 3.4 by building type.

For example, for a Fixture-Mounted Daylight Sensor installed in a gas heated building:

$$\begin{aligned} \Delta Therms &= 0.095 * 3,065 * 0.28 * (-0.01) \\ &= -0.82 \text{ Therms} \end{aligned}$$

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:

⁵⁵¹ RLW Analytics, Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, Table i -13, pg X. Spring 2007. Please note this study looks at Occupancy Sensors, however daylighting controls coincidence factor will be comparable.

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

Where:

$\Delta Therms$ = Therm impact calculated above

Heatdays = Heat season days per year

= 190⁵⁵²

For example, for a Switch (Wall) Mounted Occupancy Sensor installed in a gas heated building:

$\Delta PeakTherms$ = -1.87/190

= -0.00984 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-LICO-V03-240101

SUNSET DATE: 1/1/2025

⁵⁵² Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

3.4.13. Daylighting Control (Removed 2020)

Measure consolidated with 3.4.12 in version 5.0.

3.4.14. Multi-Level Lighting Switch

DESCRIPTION

Multi-level switching allows some of the electric lighting in a space to be switched off while maintaining a reasonably uniform distribution of light suitable for work. Multi-level switching typically use two or more separate light circuits each of which is controlled by a different switch. These circuits can be arranged in one of three ways:

- 1) Switching alternate lamps in each luminaire
- 2) Switching alternate luminaires
- 3) Switching alternate rows of luminaires

Multi-level switching is used in addition to the usual separation of lighting circuits into different functional areas and saves energy by allowing lamps to remain off when sufficient daylight is present, and by offering occupants the ability to have lower light levels for work. Additional energy can be saved by combining multi-level switching with occupancy sensors or photo-sensor controls.

Multi-level switching is required in the Commercial new construction building energy code (IECC 2012).⁵⁵³ As such this measure can only relate to the installation of new multi-level lighting switches on an existing lighting system.

This measure was developed to be applicable to Retrofit (RF) opportunities only.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient system is assumed to be a lighting system controlled by multi-level lighting controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an uncontrolled lighting system where all lights in a given area are on the same circuit or all circuits come on at the same time.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for all lighting controls is assumed to be 10 years.⁵⁵⁴

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the incremental capital cost for this measure is assumed to be \$274.⁵⁵⁵

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS⁵⁵⁶

⁵⁵³ ASHRAE 90.1-2010, IECC 2012 Lutron “Code Compliance, Commercial Application Guide”.

⁵⁵⁴ GDS Associates, Measure Life Report “Residential and Commercial/Industrial Lighting and HVAC Measures June, 2007

⁵⁵⁵ Cost of high/low control for 320W PSMH, per fixture controlled. Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009.

⁵⁵⁶ Assume ISR is 100%.

$$\Delta kWh = KW_{Controlled} * Hours * ESF * WHF_e$$

Where:

- $KW_{Controlled}$ = Total lighting load connected to the control in kilowatts. The total connected load should be collected from the customer
= Actual.
- Hours = The total annual operating hours of lighting for each type of building before occupancy sensors. This number should be collected from the customer. If no data is available the deemed average number of operating hours by building type should be used as provided in Lighting Reference Table in Section 3.4. If unknown building type, use the Nonresidential Average value.
- ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system). Use the default value of 31%.⁵⁵⁷
- WHF_e = Waste heat factor for energy to account for cooling energy savings from more efficient lighting is provided in the Lighting Reference Table in Section 3.4.

HEATING PENALTY

If electrically heated building:⁵⁵⁸

$$\Delta kWh_{heatpenalty} = KW_{Controlled} * Hours * ESF * (-IFkWh)$$

Where:

- IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

For example, for multi-level lighting switches controlling a 0.200 kW connected load:

$$\begin{aligned} \Delta kWh &= 0.200 * 3,065 * 0.31 * 1.06 \\ &= 201.4 \text{ kWh} \end{aligned}$$

For multi-level lighting switches controlling a 0.200 kW connected load and installed in a building with electric resistance heating, the electric heating penalty is:

$$\begin{aligned} \Delta kWh_{heatingpenalty} &= 0.200 * 3,065 * 0.31 * (-0.24) \\ &= -45.6 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = KW_{controlled} * ESF * WHF_d * CF$$

Where:

⁵⁵⁷ Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Page & Associates Inc. 2011
<http://eetd.lbl.gov/publications/meta-analysis-energy-savings-lighting-controls-commercial-buildings>.
 LBNL’s meta study of energy savings from lighting controls in commercial buildings bases its savings analysis on over 240 actual field installation. The report found that savings are over-represented and do not filter for external factors such as building orientation, location, use, weather, blinds, commissioning, changes in behavior after controls set etc. As such their value of 31% represented the best conservative estimate of “personal tuning” energy saving factor—that includes dimmers, bi-level and wire-less on-off switches, computer-based controls, pre-set scene selection—achieved across various building and space type, lamp and luminaire technology available in the field today.

⁵⁵⁸Negative value because this is an increase in heating consumption due to the efficient lighting.

- WHF_d = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Lighting Reference Table 3.4.
- CF = Summer Peak Coincidence Factor for the Multi-Level Lighting Switch installed is assumed to be consistent with the lighting loadshapes.⁵⁵⁹ See Lighting Reference Table in Section 3.4 for each building type. If the building type is unknown, use the Nonresidential Average value.

For example, for multi-level lighting switches controlling a 0.200 kW connected load:

$$\begin{aligned} \Delta kW &= 0.200 * 0.31 * 1.28 * 0.6907 \\ &= 0.0548 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

If gas heated building (or unknown):

$$\Delta Therms = KW_{Controlled} * Hours * ESF * (-IFTherms)$$

Where:

- IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 3.4 by building type.

For example, for multi-level lighting switches controlling a 0.200 kW connected load and installed in a gas heated building:

$$\begin{aligned} \Delta Therms &= 0.200 * 3,065 * 0.31 * (-0.01) \\ &= -1.9 \text{ therms} \end{aligned}$$

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:

- ΔTherms = Therm impact calculated above
- HeatDays = Heat season days per year
= 190⁵⁶⁰

For example, for multi-level lighting switches controlling a 0.200 kW connected load and installed in a gas heated building:

$$\begin{aligned} \Delta PeakTherms &= -1.9/190 \\ &= -0.001 \text{ therms} \end{aligned}$$

⁵⁵⁹ By applying the ESF and the same coincidence factor for general lighting savings we are in essence assuming that the savings from multi-level switching are as likely during peak periods as any other time. In the absence of better information this seems like a reasonable assumption and if anything may be on the conservative side since you might expect the peak periods to be generally sunnier and therefore more likely to have lower light levels. It is also consistent with the control type reducing the wattage lighting load, the same as the general lighting measures.

⁵⁶⁰ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-MLLS-V04-240101

SUNSET DATE: 1/1/2021*

* 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.

3.5. Miscellaneous

3.5.1. Variable Frequency Drives for Process

DESCRIPTION

This measure applies to variable frequency drives (VFDs) installed on fans and centrifugal pump motors in process applications. This characterization does not apply to positive displacement pumps. The VFD will modulate the speed of the motor when it does not need to run at full load. Theoretically, since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

The VFD is applied to a motor 1-100 HP that does not have a VFD. The application must have a variable load, and installation is to include the necessary controls as determined by a qualified engineer. Savings are based on application of VFDs to a range of baseline load conditions including no control, inlet guide vanes, and outlet guide vanes.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VFD or other methods of control. The retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves, or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VFDs that are required by IECC 2012 as adopted by the State of Iowa are not eligible to claim savings.⁵⁶¹

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for a VFD fan or centrifugal pump for a process application is 15 years.⁵⁶²

DEEMED MEASURE COST

For retrofits, actual customer-provided costs will be used when available.

For time of sale, actual costs may be used if associated baseline costs can also be estimated for the application. If actual costs are unknown, default incremental VFD costs are listed below for 1-100 HP motors.⁵⁶³

HP	Cost
1-9 HP	\$2,177
10-19 HP	\$3,123
20-29 HP	\$4,280
30-39 HP	\$5,023

⁵⁶¹ IECC provisions for existing buildings are as follows: “Additions, alterations, renovations or repairs to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portion(s) of the existing building or building system to comply with this Code”.

⁵⁶² “NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013.”

⁵⁶³ Incremental costs are sourced from the “NEEP Incremental Cost Study – Phase II Final Report, Navigant, 2013” and adjusted to account for regional labor cost differences between the Mid-Atlantic region and the state of Iowa. The Bureau of Labor Statistics, Occupational Employment Statistics, State Occupational Employment and Wage Estimates from May 2018 were leveraged in order to identify prevailing wage differences between the location of the original study and the state of Iowa.

HP	Cost
40-49 HP	\$5,766
50-59 HP	\$6,591
60-69 HP	\$7,550
70-79 HP	\$8,173
80-89 HP	\$8,796
90-100 HP	\$9,576

LOADSHAPE

Custom Loadshape

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = HP * Hours * ESF$$

Where:

- HP = Nominal horsepower of controlled motor
= Actual
- Hours = Annual operating hours of motor
= Actual
- ESF = Energy Savings Factor⁵⁶⁴
= 0.19 kWh/hp for process fans
= 0.26 kWh/hp for process centrifugal pumps

For example, a 50-horsepower VFD operating for 2,386 hours annually driving a process fan would save:

$$\begin{aligned} \Delta kWh &= 50 * 2,386 * 0.19 \\ &= 22,667 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS⁵⁶⁵

$$\Delta kW = HP * DSF$$

Where:

- HP = Nominal horsepower of controlled motor
- DSF = Summer Coincident Peak Demand Savings Factor⁵⁶⁶
= 0.16 kW/hp for process fans

⁵⁶⁴ Energy savings factors derived from analysis of 16 MEC custom VFD projects. See 'Custom Process VFD Savings Factor_2019-04-03.xlsx'.

⁵⁶⁵ Coincident demand savings for variable frequency drives for process pumps and motors are based on claimed coincident peak demand savings from 14 MEC custom projects. If a process in which the installed VFD is known to occur off peak, coincident demand savings will be zero and should be accounted for that appropriately.

⁵⁶⁶ Demand savings factors derived from analysis of 14 MEC custom VFD projects. See 'Custom Process VFD Savings Factor_2019-04-03.xlsx'

= 0.26 kW/hp for process centrifugal pumps

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: NR-MS-C-VFDP-V04-230101

SUNSET DATE: 1/1/2026

3.5.2. Clothes Washer

DESCRIPTION

This measure relates to the installation of a commercial grade clothes washer meeting the ENERGY STAR minimum qualifications. Note it is assumed the DHW and dryer fuels of the installations 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

The Commercial grade Clothes washer must meet the ENERGY STAR minimum qualifications (provided in the table below), as required by the program⁵⁶⁷.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a commercial grade clothes washer meeting the minimum federal baseline as of January 2018.⁵⁶⁸

Efficiency Level		Top loading	Front Loading
Baseline	Federal Standard	≥1.35 MEF _{J2} , ≤8.8 IWF	≥2.00 MEF _{J2} , ≤4.1 IWF
Efficient	ENERGY STAR	≥2.2 MEF _{J2} , ≤4.0 IWF	

The Modified Energy Factor (MEF_{J2}) includes unit operation, water heating, and drying energy use, with the higher the value the more efficient the unit; *"The quotient of the 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, and the energy required for removal of the remaining moisture in the wash load."*

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 wash cycles, divided by the capacity of the clothes washer."*⁵⁶⁹

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 11 years.⁵⁷⁰

DEEMED MEASURE COST

The incremental cost is assumed to be \$190.⁵⁷¹

LOADSHAPE

Loadshape RE14 - Residential Clothes Washer⁵⁷²

⁵⁶⁷ Current ENERGY STAR Specification V8.1 active 4/22/21; no changes to efficiency requirements since v8.0. They have just included more product types.

⁵⁶⁸ See Federal Standard 10 CFR 431.156.

⁵⁶⁹ Definitions provided on the Energy star website.

⁵⁷⁰ Appliance Magazine, January 2011 as referenced in ENERGY STAR Commercial Clothes Washer Calculator.

⁵⁷¹ Based on Industry Data 2015 as referenced in ENERGY STAR Commercial Clothes Washer Calculator.

⁵⁷² The Residential Clothes Washer loadshape is considered a reasonable proxy for commercial applications – in the absence of any other empirical basis.

Loadshape G01 - Flat (gas)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Capacity = Clothes Washer capacity (cubic feet)
 = Actual, if capacity is unknown, assume 3.45 cubic feet⁵⁷³

MEFbase = Modified Energy Factor of baseline unit

Efficiency Level	MEFbase		
	Top loading	Front Loading	Weighted Average ⁵⁷⁴
Federal Standard	1.35	2.0	1.4

MEFeff = Modified Energy Factor of efficient unit
 = Actual, if unknown, assume average values provided below.

Efficiency Level	MEFeff ⁵⁷⁵		
	Top loading	Front Loading	Weighted Average
ENERGY STAR	2.2		

Ncycles = Number of Cycles per year
 = 2,190⁵⁷⁶

%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)

⁵⁷³ Based on the average clothes washer volume of all units that pass the Federal Standard on the CCMS database of commercial Clothes Washer products (accessed April 2023).

⁵⁷⁴ Weighted average MEF of Federal Standard rating for Front Loading and Top Loading units. Baseline weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR commercial product in the CCMS database and ENERGY STAR weighting is based on eligible products as of April 2023

⁵⁷⁵ ENERGY STAR Program Requirements Product Specifications for Clothes Washers, v8.0, effective February 5, 2018. Modified Energy Factor for commercial clothes washer

⁵⁷⁶ Based on DOE Technical Support Document, 2009; Chapter 8 Life-Cycle Cost and Payback Period Analysis, p 8-15.

	Percentage of Total Energy Consumption ⁵⁷⁷		
	%CW	%DHW	%Dryer
Federal Standard	7.0%	28.1%	64.9%
ENERGY STAR	3.9%	15.5%	80.6%

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

DHW fuel	%Electric _{DHW}
Electric	100%
Natural Gas	0%

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

Dryer fuel	%Electric _{Dryer}
Electric	100%
Natural Gas	0%

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:⁵⁷⁸

Efficiency Level	ΔkWh			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	2101.8	1080.0	1277.2	255.4

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Energy Savings as calculated above

Hours = Assumed Run hours of Clothes Washer
= 1643 hours⁵⁷⁹

CF = Summer Peak Coincidence Factor for measure
= 50%⁵⁸⁰

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

⁵⁷⁷ 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 data provided in the ENERGY STAR Calculator for Commercial Clothes Washers as provided in the IPL Non-Residential Prescriptive Program workbook (no longer available online).

⁵⁷⁸ Note that the baseline savings is based on the weighted average baseline MEF (as opposed to assuming Front baseline for Front efficient unit and Top baseline for Top efficient unit). The reasoning is that the support of the program of more efficient units (which are predominately front loading) will result in some participants switching from planned purchase of a top loader to a front loader.

⁵⁷⁹ Assuming an average load runs for an estimated 45 minutes.

⁵⁸⁰ In the absence of any commercial specific data, this is estimated at 50%.

Efficiency Level	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.480	0.247	0.292	0.058

NATURAL GAS SAVINGS

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

Where:

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

DHW fuel	%Gas _{DHW}
Electric	0%
Natural Gas	100%

R_{eff} = Recovery efficiency factor

= 1.26⁵⁸¹

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

Dryer fuel	%Gas _{Dryer}
Electric	0%
Natural Gas	100%

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:

Efficiency Level	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.0	43.9	28.1	72.1

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:

⁵⁸¹ To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

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

Where:

$\Delta Therms$ = Therm impact calculated above
 365 = Days per year

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

Efficiency Level	$\Delta PeakTherms$			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.000	0.120	0.077	0.197

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water (gallons) = Capacity * (IWF_{base} - IWF_{eff}) * N_{cycles}$$

Where:

IWF_{base} = Water Factor of baseline clothes washer

Efficiency Level	IWF_{base}		
	Top loading	Front Loading	Weighted Average ⁵⁸²
Federal Standard	8.8	4.1	8.7

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			$\Delta Water$ (gallons per year)
	Top Loaders	Front Loaders	Weighted Average	Weighted Average
Federal Standard	8.8	4.1	8.7	n/a
ENERGY STAR	4.5			31,682

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MS-CLWA-V03-240101

SUNSET DATE: 1/1/2026

⁵⁸² Weighted average IWF of Federal Standard rating for Front Loading and Top Loading units. Baseline weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR commercial product in the CCMS and ENERGY STAR weighting is based on eligible products as of April 2023.

3.5.3. Motors

DESCRIPTION

Electric motor systems consume large amounts of electrical energy and can provide an opportunity for significant energy savings. Energy consumption represents more than 97% of the total motor operating costs over the motors lifetime, and when replacing a working motor or a near-failure motor the energy efficiency of electrical motors can be improved by 20-30% on average, resulting in significant energy and cost savings.⁵⁸³

This measure applies to one-for-one replacement of old failed/near failure 1-350 horsepower⁵⁸⁴ constant speed and uniformly loaded motors with new energy efficiency motors of the same rated horsepower that exceed NEMA Premium Efficiency levels.

This measure characterizes HVAC fan or pumping motors and was developed to be applicable to the following program types: Time of Sale (TOS)

DEFINITION OF EFFICIENT EQUIPMENT

The new motor efficiency must meet program standards which exceed NEMA Premium Efficiency as listed and recognized by CEE to meet their criteria for energy efficiency and be compliant with DOE's amended energy conservation standards effective June 1, 2016.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a motor meeting Federal minimum efficiency requirements.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years.⁵⁸⁵

DEEMED MEASURE COST

Actual costs may be used if associated baseline costs can also be estimated for the application. If actual costs are unknown, incremental costs, regardless of motor type are based on nominal horsepower per the following relationship:⁵⁸⁶

For motors up to and equal to 300 horsepower: Cost = \$20.12 * (HP rating) + \$152.04

For motors larger than 300 horsepower: Cost = \$23.82 * (HP rating) - \$1,958.88

LOADSHAPE

Loadshape NRE03 – Non-Residential Industrial Motor

⁵⁸³ Premium efficiency standards and sound motor management strategies as outlined by the Motor Decisions MatterSM (MDM) lead to reduced energy costs and increase productivity. See reference file "Motor Planning Kit."

⁵⁸⁴ For 1-200 horsepower general purpose motors 1200 rpm, 1800 rpm, 3600 rpm, IESA is equivalent to NEMA Premium®. For 200-350 horsepower general purpose motors 1200 rpm, 1800 rpm, 3600 rpm, federal requirements are equivalent to NEMA Premium specifications. See NEMA MG1-2011 Table 12-12 for more information <http://www.nema.org>.

⁵⁸⁵ Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Measure Life Study, KEMA, August 25, 2009.

⁵⁸⁶ Based on the dataset provided in DOCKET NO. E,G002/CIP-20-473 MINNESOTA ELECTRIC AND NATURAL GAS CONSERVATION IMPROVEMENT PROGRAM 2021-2023.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS⁵⁸⁷

$$\Delta kWh = (kW_{Base} - kW_{EE}) * Hours$$

$$kW_{Base} = \left(0.746 * HP * \frac{LF}{\eta_{Bmotor}} \right)$$

$$kW_{EE} = \left(0.746 * HP * \frac{LF}{\eta_{EEmotor}} \right)$$

Where:

0.746 = Conversion factor for HP to kWh

HP = Nominal horsepower of controlled motor

= Actual

LF = Load Factor; Motor Load at Fan/Pump Design CFM (Default = 75%)⁵⁸⁸

η_{Bmotor} = Federal baseline nominal/nameplate motor efficiency as shown in tables below for Open Drip Proof (ODP) and Totally Enclosed Fan Cooled (TEFC), based on motor design type.

Nominal Full-Load Efficiencies of NEMA Design A, NEMA Design B and IEC Design N Motors (Excluding Fire Pump Electric Motors) at 60 Hz:

Motor horsepower/standard kilowatt equivalent	Nominal full-load efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1/.75	77	77	85.5	85.5	82.5	82.5	75.5	75.5
1.5/1.1	84	84	86.5	86.5	87.5	86.5	78.5	77
2/1.5	85.5	85.5	86.5	86.5	88.5	87.5	84	86.5
3/2.2	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5/3.7	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5/5.5	89.5	88.5	91.7	91	91	90.2	86.5	89.5
10/7.5	90.2	89.5	91.7	91.7	91	91.7	89.5	90.2
15/11	91	90.2	92.4	93	91.7	91.7	89.5	90.2
20/15	91	91	93	93	91.7	92.4	90.2	91
25/18.5	91.7	91.7	93.6	93.6	93	93	90.2	91
30/22	91.7	91.7	93.6	94.1	93	93.6	91.7	91.7
40/30	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50/37	93	93	94.5	94.5	94.1	94.1	92.4	92.4
60/45	93.6	93.6	95	95	94.5	94.5	92.4	93
75/55	93.6	93.6	95.4	95	94.5	94.5	93.6	94.1
100/75	94.1	93.6	95.4	95.4	95	95	93.6	94.1

⁵⁸⁷ Prevailing energy Savings Methodology for motor measures as highlighted by SEEAAction Scoping Study to Evaluate Feasibility of national Databases for EM&V Documents and Measure Savings, June 2011.

⁵⁸⁸ Basic load measurements should be collected as motors do not run at the same load factor. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is therefore assumed to be 0.75. *Determining Electric Motor Load and Efficiency*, US DOE Motor Challenge, a program of the US Department of Energy, www1.eere.energy.gov/industry/bestpractices/pdfs/10097517.pdf.

Motor horsepower/standard kilowatt equivalent	Nominal full-load efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
125/90	95	94.1	95.4	95.4	95	95	94.1	94.1
150/110	95	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200/150	95.4	95	96.2	95.8	95.8	95.4	94.5	94.1
250/186	95.8	95	96.2	95.8	95.8	95.8	95	95
300/224	95.8	95.4	96.2	95.8	95.8	95.8		
350/261	95.8	95.4	96.2	95.8	95.8	95.8		
400/298	95.8	95.8	96.2	95.8				
450/336	95.8	96.2	96.2	96.2				
500/373	95.8	96.2	96.2	96.2				

Nominal Full-Load Efficiencies of NEMA Design C and IEC Design H Motors at 60 Hz:

Motor horsepower/standard kilowatt equivalent	Nominal full-load efficiency (%)					
	4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1/.75	85.5	85.5	82.5	82.5	75.5	75.5
1.5/1.1	86.5	86.5	87.5	86.5	78.5	77
2/1.5	86.5	86.5	88.5	87.5	84	86.5
3/2.2	89.5	89.5	89.5	88.5	85.5	87.5
5/3.7	89.5	89.5	89.5	89.5	86.5	88.5
7.5/5.5	91.7	91	91	90.2	86.5	89.5
10/7.5	91.7	91.7	91	91.7	89.5	90.2
15/11	92.4	93	91.7	91.7	89.5	90.2
20/15	93	93	91.7	92.4	90.2	91
25/18.5	93.6	93.6	93	93	90.2	91
30/22	93.6	94.1	93	93.6	91.7	91.7
40/30	94.1	94.1	94.1	94.1	91.7	91.7
50/37	94.5	94.5	94.1	94.1	92.4	92.4
60/45	95	95	94.5	94.5	92.4	93
75/55	95.4	95	94.5	94.5	93.6	94.1
100/75	95.4	95.4	95	95	93.6	94.1
125/90	95.4	95.4	95	95	94.1	94.1
150/110	95.8	95.8	95.8	95.4	94.1	94.1
200/150	96.2	95.8	95.8	95.4	94.5	94.1

$\eta_{E\text{motor}}$ = Efficient motor nominal/nameplate motor efficiency
 = Actual

Hours = Hours for HVAC motors are found in table below:⁵⁸⁹

Building Type	Hot Water Pump m Motor Hours	Chilled Water Pump Motor Hours	Fan Motor Run Hours
Convenience*	3628	2690	4630
Education	6367	2796	3544

⁵⁸⁹ All values taken from IA VFD Fan and pump measure including building type to ensure consistency across IA TRM. Building types denoted with an asterisk indicate values were referenced from the ComEd TRM June 1, 2010 page 139. As we gather more information on prevalent types of participating motors, VEIC will add additional columns

Building Type	Hot Water Pump m Motor Hours	Chilled Water Pump Motor Hours	Fan Motor Run Hours
Grocery	6499	2725	8743
Health	8720	4770	3478
Hospital	8289	8760	4570
Industrial*	3977	3080	2850
Lodging	5500	7909	3909
Multifamily	5382	5084	8760
Office - Large	5316	4596	2662
Office - Small	1952	2138	7667
Religious*	4763	2223	2412
Restaurant	3027	2719	7300
Retail – Large*	4218	2405	4065
Retail - Small	3029	2266	7410
Warehouse*	4100	1788	2920
Nonresidential (average)	3659	2182	4978

For all non HVAC applications, hour of use are found below:⁵⁹⁰

Unit HP Range	Mean Annual HOU
1-5	2,745
6-20	3,391
21-50	4,067
51-100	5,329
101-200	5,200
201-350	6,132

For example, a 5-horsepower, enclosed, 4-pole, design type A motor on a chilled water pump with a load factor of 0.8 and an efficiency of 90.5% in a hospital would save:

$$\begin{aligned} \Delta kWh &= 0.746 * 5 * (0.8/.895 - 0.8/0.905) * 8760 \\ &= 322.7 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\begin{aligned} \Delta kW &= (kW_{Base} - kW_{EE}) * CF \\ kW_{Base} &= \left(0.746 * HP * \frac{LF}{\eta_{Bmotor}} \right) \\ kW_{EE} &= \left(0.746 * HP * \frac{LF}{\eta_{EEmotor}} \right) \end{aligned}$$

Where:

$$CF = 79.3\%^{591}$$

All other variables provided above.

⁵⁹⁰ United States Industrial Electric Motor Systems Mark Opportunities Assessment (p. 66), December 2012: http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

⁵⁹¹ Industrial Motor CF in IA_Electric Loadshapes – Working Draft.xls

For example, a 5-horsepower, enclosed, 4-pole, design type A motor on a chilled water pump with a load factor of 0.8 and an efficiency of 90.5% in a hospital would save:

$$\begin{aligned} \Delta kW &= 0.746 * 5 * (0.8/.895 - 0.8/0.905) * 0.793 \\ &= 0.029 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

There are no expected fossil fuel impacts for this measure.⁵⁹²

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MCS-MOTR-V04-220101

SUNSET DATE: 1/1/2025

⁵⁹² Consider updating measure to include heating and cooling savings in future revisions.

3.5.4. Forklift Battery Charger

DESCRIPTION

This measure applies to industrial high frequency battery chargers, used for industrial equipment such as fork lifts, replacing existing SCR (silicon controlled rectifier) or ferroresonant charging technology. High frequency battery chargers have a greater system efficiency.

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

DEFINITION OF EFFICIENT EQUIPMENT

High frequency battery charger systems with minimum Power Conversion Efficiency of 90% and a minimum 8-hour shift operation five days per week.

DEFINITION OF BASELINE EQUIPMENT

SCR or ferroresonant battery charger systems with minimum 8-hour shift operation five days per week.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

15 years⁵⁹³

DEEMED MEASURE COST

The deemed incremental measure cost is \$400.⁵⁹⁴

LOADSHAPE

Loadshape NRE13 - Indust. 1-shift (8/5)

Loadshape NRE14 - Indust. 2-shift (16/5)

Loadshape NRE15 - Indust. 3-shift (24/5)

Loadshape NRE16 - Indust. 4-shift (24/7)

Algorithm

ELECTRIC ENERGY SAVINGS

$$\Delta\text{kWh} = (\text{CAP} * \text{DOD}) * \text{CHG} * (\text{CR}_B / \text{PC}_B - \text{CR}_{EE} / \text{PC}_{EE}) * \text{WHFe}$$

Where:

CAP = Capacity of Battery

= Use actual battery capacity, otherwise use a default value of 35 kWh.⁵⁹⁵

DOD = Depth of Discharge

= Use actual depth of discharge, otherwise use a default value of 80%.⁵⁹⁶

⁵⁹³ Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 45

⁵⁹⁴ Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 42

⁵⁹⁵ Jacob V. Renquist, Brian Dickman, and Thomas H. Bradley, “Economic Comparison of fuel cell powered forklifts to battery powered forklifts”, International Journal of Hydrogen Energy Volume 37, Issue 17, (2012): 2.

⁵⁹⁶ Ryan Matley, “Measuring Energy Efficiency Improvements in Industrial Battery Chargers”, (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4.

CHG = Number of Charges per year
 = Use actual number of annual charges, if unknown use values below based on the type of operations:⁵⁹⁷

Standard Operations	Number of Charges per year
1-shift (8 hrs/day – 5 days/week)	520
2-shift (16 hrs/day – 5 days/week)	1040
3-shift (24 hrs/day – 5 days/week)	1560
4-shift (24 hrs/day – 7 days/week)	2184

CR_B = Baseline Charge Return Factor
 = 1.2485⁵⁹⁸

PC_B = Baseline Power Conversion Efficiency
 = 0.84⁵⁹⁹

CR_{EE} = Efficient Charge Return Factor
 = 1.107⁶⁰⁰

PC_{EE} = Efficient Power Conversion Efficiency
 = 0.89⁶⁰¹

WHF_e = Waste heat factor for energy to account for cooling energy savings from reduced waste heat from the battery charger
 = 1.09 for cooled warehouse, 1.0 for uncooled warehouse and 1.29 for refrigerated buildings.⁶⁰²

Default savings using defaults provided above are provided below:

Standard Operations	ΔkWh		
	Cooled warehouse	Uncooled warehouse	Refrigerated warehouse
1-shift (8 hrs/day – 5 days/week)	3,848.4	3,530.6	4,554.5
2-shift (16 hrs/day – 5 days/week)	7,696.8	7,061.3	9,109.1
3-shift (24 hrs/day – 5 days/week)	11,545.2	10,591.9	13,663.6
4-shift (24 hrs/day – 7 days/week)	16,163.3	14,828.7	19,129.0

Heating Penalty:

⁵⁹⁷ Number of charges is derived from the following reference and adjusted to the hours and days of the different types of shift operations. These values are based on an estimated 2-charge per 8-hour workday. See reference file: Ryan Matley, “Measuring Energy Efficiency Improvements in Industrial Battery Chargers”, (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4.

⁵⁹⁸ Ryan Matley, “Measuring Energy Efficiency Improvements in Industrial Battery Chargers”, (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4 (average of SCR and Ferroresonant).

⁵⁹⁹ Ibid.

⁶⁰⁰ Ibid.

⁶⁰¹ Ibid.

⁶⁰² WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

If electrically heated building:⁶⁰³

$$\Delta kWh_{heatpenalty} = (CAP * DOD) * CHG * (CRB / PCB - CREE / PCEE) * (-IFkWh)$$

Where:

IFkWh = Heating Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the battery charger
 = 0.44 if resistance heat, 0.19 if heat pump, 0 if unheated.⁶⁰⁴

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (PF_B / PC_B - PF_{EE} / PC_{EE}) * Volts_{DC} * Amps_{DC} / 1000 * WHFd * CF$$

Where:

PF_B = Power factor of baseline charger
 = 0.9095⁶⁰⁵

PF_{EE} = Power factor of high frequency charger
 = 0.9370⁶⁰⁶

Volts_{DC} = Actual DC rated voltage of charger (assumed baseline charger is replaced with same rated high frequency unit)
 = Use actual battery DC voltage rating, otherwise use a default value of 48 volts.⁶⁰⁷

Amps_{DC} = Actual DC rated amperage of charger (assumed baseline charger is replaced with same rated high frequency unit)
 = Use actual battery DC ampere rating, otherwise use a default value of 81 amps.⁶⁰⁸

1,000 = watt to kilowatt conversion factor

WHFd = Waste heat factor for demand to account for cooling energy savings from reduced waste heat from the battery charger
 = 1.43 for cooled warehouse, 1.0 for uncooled warehouse and 1.29 for refrigerated buildings.⁶⁰⁹

CF = Summer Coincident Peak Factor for this measure
 = 0.0% (for 1- and 2-shift operation)⁶¹⁰

⁶⁰³ Results in a negative value because this is an increase in heating consumption due to the less waste heat.

⁶⁰⁴ WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

⁶⁰⁵ Ibid.

⁶⁰⁶ Ibid.

⁶⁰⁷ Voltage rating based on the assumption of 35kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5 hour charge cycle. Pacific Gas & Electric, “Emerging Technologies Program Application Assessment Report #0808”, Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. Page 8, Table 3.

⁶⁰⁸ Ampere rating based on the assumption of 35kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5 hour charge cycle. Pacific Gas & Electric, “Emerging Technologies Program Application Assessment Report #0808”, Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. Page 8, Table 3.

⁶⁰⁹ WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

⁶¹⁰ Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009.

= 1.0 (for 3- and 4-shift operation)⁶¹¹

Other variables as provided above.

Default savings using defaults provided above are provided below:

Standard Operations	ΔkW		
	Cooled warehouse	Uncooled warehouse	Refrigerated warehouse
1-shift (8 hrs/day – 5 days/week)	0	0	0
2-shift (16 hrs/day – 5 days/week)	0	0	0
3-shift (24 hrs/day – 5 days/week)	0.1664	0.1165	0.1501
4-shift (24 hrs/day – 7 days/week)	0.1664	0.1165	0.1501

NATURAL GAS SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):⁶¹²

$$\Delta Therms = (CAP * DOD) * CHG * (CRB / PCB - CREE / PCEE) * (-IFTherms)$$

Where:

IFTherms = Heating Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the battery charger
 = 0.019 if gas heated, 0 if unheated⁶¹³

PEAK GAS SAVINGS

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

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

Where:

ΔTherms = Therm impact calculated above
 HeatDays = Heat season days per year
 = 190⁶¹⁴

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MS-C-BACH-V02-240101

⁶¹¹ Ibid.

⁶¹² Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁶¹³ WHFs are consistent with those provided in the lighting section. This assumes similar patterns of operation for lighting and battery chargers.

⁶¹⁴ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

SUNSET DATE: 1/1/2026

3.6. Food Service

3.6.1. Dishwasher

DESCRIPTION

This measure applies to ENERGY STAR high and low temperature under counter, stationary single tank door type, single tank conveyor, and multi tank conveyor dishwashers, as well as to high temperature pot, pan, and utensil dishwashers installed in a commercial kitchen. ENERGY STAR commercial dishwashers use approximately 40% less energy and water than standard models.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new ENERGY STAR certified dishwasher meeting idle energy rate (kW) and water consumption (gallons/rack) limits, as determined by both machine type and sanitation approach (chemical/low temperature versus high temperature).

ENERGY STAR Requirements (Version 3.0, Effective July 27, 2021)

Dishwasher Type	High Temp Efficiency Requirements			Low Temp Efficiency Requirements		
	Idle Energy Rate	Washing Energy	Water Consumption	Idle Energy Rate	Washing Energy	Water Consumption
Under Counter	≤ 0.30 kW	≤ 0.35 kWh/rack	≤ 0.86 GPR	≤ 0.25 kW	≤ 0.15 kWh/rack	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.55 kW	≤ 0.35 kWh/rack	≤ 0.89 GPR	≤ 0.30 kW	≤ 0.15 kWh/rack	≤ 1.18 GPR
Pot, Pan, and Utensil	≤ 0.90 kW	≤ 0.55 + 0.05 * SF _{rack}	≤ 0.58 GPSF	N/A		
Single Tank Conveyor	≤ 1.20 kW	≤ 0.36 kWh/rack	≤ 0.70 GPR	≤ 0.85 kW	≤ 0.16 kWh/rack	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 1.85 kW	≤ 0.36 kWh/rack	≤ 0.54 GPR	≤ 1.00 kW	≤ 0.22 kWh/rack	≤ 0.54 GPR

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new dishwasher that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be:⁶¹⁵

	Dishwasher Type	Equipment Life
Low Temp	Under Counter	10
	Stationary Single Tank Door	15
	Single Tank Conveyor	20
	Multi Tank Conveyor	20
High Temp	Under Counter	10
	Stationary Single Tank Door	15
	Single Tank Conveyor	20
	Multi Tank Conveyor	20
	Pot, Pan, and Utensil	10

⁶¹⁵ Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “EPA/FSTC research on available models, 2013”

https://www.energystar.gov/sites/default/files/asset/document/CFS_calculator_07-15-2021.xlsx

DEEMED MEASURE COST

The incremental capital cost for this measure is:⁶¹⁶

Dishwasher Type		Incremental Cost
Low Temp	Under Counter	\$234
	Stationary Single Tank Door	\$662
	Single Tank Conveyor	\$0
	Multi Tank Conveyor	\$970
High Temp	Under Counter	\$2,025
	Stationary Single Tank Door	\$995
	Single Tank Conveyor	\$2050
	Multi Tank Conveyor	\$970
	Pot, Pan, and Utensil	\$1710

LOADSHAPE

Loadshape NREW12 - Nonresidential Electric Hot Water – Restaurant

Loadshape NRGW12 - Nonresidential Gas Hot Water – Restaurant

Algorithm

CALCULATION OF SAVINGS

ENERGY STAR dishwashers save energy in three categories: building water heating, booster water heating, and idle energy. Building water heating and booster water heating could be either electric or natural gas.

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed values found within the tables that follow.

$$\Delta kWh^{617} = \Delta BuildingEnergy + \Delta BoosterEnergy^{618} + \Delta IdleEnergy$$

Where:

$$\begin{aligned} \Delta BuildingEnergy &= \text{Change in annual electric energy consumption of building water heater} \\ &= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] - \\ &\quad [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] \\ \Delta BoosterEnergy &= \text{Annual electric energy consumption of booster water heater} \\ &= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] - \\ &\quad [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] \end{aligned}$$

⁶¹⁶ Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “Difference between a similar ENERGY STAR and non-qualifying model EPA research using AutoQuotes, 2016 (for high/low temp undercounter/single door) and 2012 (all other types)”.

⁶¹⁷ Algorithms and assumptions except for inlet water temperature increase for building water heaters derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

⁶¹⁸ Booster water heater energy only applies to high-temperature dishwashers.

$$\Delta \text{IdleEnergy} = \text{Annual idle electric energy consumption of dishwasher}$$

$$= [\text{IdleDraw}_{\text{Base}} * (\text{Hours} * \text{Days} - \text{Days} * \text{RacksWashed} * \text{WashTime} \div 60)] - [\text{IdleDraw}_{\text{ESTAR}} * (\text{Hours} * \text{Days} - \text{Days} * \text{RacksWashed} * \text{WashTime} \div 60)]$$

Where:

- $\text{WaterUse}_{\text{Base}}$ = Water use per rack (gal) of baseline dishwasher
 = Use value from table below as determined by machine type and sanitation method
- $\text{WaterUse}_{\text{ESTAR}}$ = Water use per rack (gal) of ENERGY STAR dishwasher
 = Custom or if unknown, use value from table below as determined by machine type and sanitation method
- RacksWashed = Number of racks washed per day
 = Custom or if unknown, use value from table below as determined by machine type and sanitation method
- Days = Annual days of dishwasher operation
 = Custom or if unknown, use 365.25 days per year
- ΔT_{in} = Inlet water temperature increase (°F)
 = Custom or if unknown, use 83.5 °F for building water heaters⁶¹⁹ and 40 °F for booster water heaters
- 1.0 = Specific heat of water (Btu/lb/°F)
- 8.2 = Density of water (lb/gal)
- $\text{Eff}_{\text{Heater}}$ = Efficiency of water heater
 = Custom or if unknown, use 98% for electric building and booster water heaters
- 3,412 = kWh to Btu conversion factor
- $\text{IdleDraw}_{\text{Base}}$ = Idle power draw (kW) of baseline dishwasher
 = Use value from table below as determined by machine type and sanitation method
- $\text{IdleDraw}_{\text{ESTAR}}$ = Idle power draw (kW) of ENERGY STAR dishwasher
 = Custom or if unknown, use value from table below as determined by machine type and sanitation method
- Hours = Average daily hours of dishwasher operation
 = Custom or if unknown, use 18 hours per day
- WashTime = Typical wash time (min)
 = Custom or if unknown, use value from table below as determined by machine type and sanitation method
- 60 = Minutes to hours conversion factor

⁶¹⁹ Inlet water temperature increase for building water heaters based on 140 °F building water heater set point and 56.5 °F inlet water temperature to the DHW system.

For example, an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:

$$\Delta kWh = \Delta \text{BuildingEnergy} + \Delta \text{BoosterEnergy} + \Delta \text{IdleEnergy}$$

Where:

$$\begin{aligned} \Delta \text{BuildingEnergy} &= [(1.09 * 75 * 365.25) * (83.5 * 1.0 * 8.2 \div 0.98 \div 3,412)] - [(0.86 * 75 * 365.25) * (83.5 * 1.0 * 8.2 \div 0.98 \div 3,412)] \\ &= 1,291.5 \text{ kWh} \\ \Delta \text{BoosterEnergy} &= [(1.09 * 75 * 365.25) * (40 * 1.0 * 8.2 \div 0.98 \div 3,412)] - [(0.86 * 75 * 365.25) * (40 * 1.0 * 8.2 \div 0.98 \div 3,412)] \\ &= 618.7 \text{ kWh} \\ \Delta \text{IdleEnergy} &= [0.76 * (18 * 365.25 - 365.25 * 75 * 2.0 \div 60)] - \\ & \quad [0.30 * (18 * 365.25 - 365.25 * 75 * 2.0 \div 60)] \\ &= 2604 \text{ kWh} \\ \Delta kWh &= 1,291.5 + 618.7 + 2,604 \\ &= 4,514 \text{ kWh} \end{aligned}$$

Default values for WaterUse, RacksWashed, kW_{Idle}, and WashTime are presented in the table below.

	RacksWashed	WashTime	WaterUse		IdleDraw	
Low Temperature	All Dishwashers	All Dishwashers	Conventional	ENERGY STAR	Conventional	ENERGY STAR
Under Counter	75	2.0	1.73	1.19	0.50	0.25
Stationary Single Tank Door	280	1.5	2.10	1.18	0.60	0.30
Single Tank Conveyor	400	0.3	1.31	0.79	1.60	0.85
Multi Tank Conveyor	600	0.3	1.04	0.54	2.00	1.00
High Temperature	All Dishwashers	All Dishwashers	Conventional	ENERGY STAR	Conventional	ENERGY STAR
Under Counter	75	2.0	1.09	0.86	0.76	0.30
Stationary Single Tank Door	280	1.0	1.29	0.89	0.87	0.55
Single Tank Conveyor	400	0.3	0.87	0.70	1.93	1.20
Multi Tank Conveyor	600	0.2	0.97	0.54	2.59	1.85
Pot, Pan, and Utensil	280	3.0	0.70	0.58	1.20	0.90

Savings for all water heating combinations are presented in the tables below.

Electric building and electric booster water heating

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	12,545.1	8,097.5	4,447.6
	Stationary Single Tank Door	46,434.3	25,942.4	20,491.9
	Single Tank Conveyor	48,582.3	28,626.3	19,956.0
	Multi Tank Conveyor	57,676.4	29,736.7	27,939.8
High Temp	Under Counter	13,355.3	8,840.9	4,514.4
	Stationary Single Tank Door	44,234.7	30,273.9	13,960.8
	Single Tank Conveyor	49,815.1	38,018.9	11,796.2
	Multi Tank Conveyor	79,584.3	46,689.9	32,894.4

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
	Pot, Pan, and Utensil	23,457.5	19,298.4	4,159.0

Electric building and natural gas booster water heating

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	12,545.1	8,097.5	4,447.6
	Stationary Single Tank Door	46,434.3	25,942.4	20,491.9
	Single Tank Conveyor	48,582.3	28,626.3	19,956.0
	Multi Tank Conveyor	57,676.4	29,736.7	27,939.8
High Temp	Under Counter	10,423.3	6,527.5	3,895.7
	Stationary Single Tank Door	31,280.0	21,336.1	9,943.9
	Single Tank Conveyor	37,333.7	27,976.4	9,357.3
	Multi Tank Conveyor	58,710.4	35,069.3	23,641.0
	Pot, Pan, and Utensil	16,427.7	13,473.8	2,953.9

Natural gas building and electric booster water heating

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	2,830.7	1,415.3	1,415.3
	Stationary Single Tank Door	2,410.7	1,205.3	1,205.3
	Single Tank Conveyor	9,350.4	4,967.4	4,383.0
	Multi Tank Conveyor	10,957.5	5,478.8	5,478.8
High Temp	Under Counter	7,234.7	4,011.8	3,222.9
	Stationary Single Tank Door	17,191.7	11,616.3	5,575.4
	Single Tank Conveyor	23,760.3	17,055.3	6,705.0
	Multi Tank Conveyor	36,009.9	22,432.0	13,578.0
	Pot, Pan, and Utensil	8,782.9	7,139.5	1,643.4

Natural gas building and natural gas booster water heating

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	2,830.7	1,415.3	1,415.3
	Stationary Single Tank Door	2,410.7	1,205.3	1,205.3
	Single Tank Conveyor	9,350.4	4,967.4	4,383.0
	Multi Tank Conveyor	10,957.5	5,478.8	5,478.8
High Temp	Under Counter	4,302.6	1,698.4	2,604.2
	Stationary Single Tank Door	4,236.9	2,678.5	1,558.4
	Single Tank Conveyor	11,278.9	7,012.8	4,266.1
	Multi Tank Conveyor	15,136.0	10,811.4	4,324.6
	Pot, Pan, and Utensil	1,753.2	1,314.9	438.3

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 63.8%

Other variables as defined above.

For example, an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:

$$\begin{aligned} \Delta kW &= 4514 / (18 * 365.25) * 0.638 \\ &= 0.4380 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms^{620} = \Delta BuildingEnergy + \Delta BoosterEnergy$$

Where:

$\Delta BuildingEnergy$ = Change in annual natural gas consumption of building water heater

$$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)]$$

$\Delta BoosterEnergy$ = Change in annual natural gas consumption of booster water heater

$$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)]$$

Where:

Eff_{Heater} = Efficiency of water heater
= Custom or 78% for gas building⁶²¹ and 80% for gas booster water heaters

100,000 = Therms to Btu conversion factor

Other variables as defined above.

For example, an ENERGY STAR high-temperature, under counter dishwasher with gas building and gas booster water heating with defaults from the calculation above and the table within the electric energy savings characterization would save:

$$\Delta Therms = \Delta BuildingEnergy + \Delta BoosterEnergy$$

Where:

$$\begin{aligned} \Delta BuildingEnergy &= [(1.09 * 75 * 365.25) * (83.5 * 1.0 * 8.2 \div 0.78 \div 100,000)] - [(0.86 * 75 * 365.25) * (83.5 * 1.0 * 8.2 \div 0.78 \div 100,000)] \\ &= 55.4 \text{ therms} \end{aligned}$$

$$\begin{aligned} \Delta BoosterEnergy &= [(1.09 * 75 * 365.25) * (40 * 1.0 * 8.2 \div 0.80 \div 100,000)] - [(0.86 * 75 * 365.25) * (40 * 1.0 * 8.2 \div 0.80 \div 100,000)] \\ &= 25.9 \text{ therms} \end{aligned}$$

$$\begin{aligned} \Delta Therms &= 55.4 + 25.9 \\ &= 81.2 \text{ therms} \end{aligned}$$

⁶²⁰ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, except for inlet water temperature increase for building water heaters and efficiency of gas building water heater

⁶²¹ 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%.

Savings for all water heating combinations are presented in the tables below.

Electric building and natural gas booster water heating

Dishwasher type		Therms _{Base}	Therms _{ESTAR}	ΔTherms
Low Temp	Under Counter	NA	NA	NA
	Stationary Single Tank Door	NA	NA	NA
	Single Tank Conveyor	NA	NA	NA
	Multi Tank Conveyor	NA	NA	NA
High Temp	Under Counter	122.6	96.7	25.9
	Stationary Single Tank Door	541.5	373.6	167.9
	Single Tank Conveyor	521.7	419.7	101.9
	Multi Tank Conveyor	872.5	485.7	386.8
	Pot, Pan, and Utensil	293.8	243.5	50.4

Natural gas building and natural gas booster water heating

Dishwasher type		Therms _{Base}	Therms _{ESTAR}	ΔTherms
Low Temp	Under Counter	416.4	286.5	130.0
	Stationary Single Tank Door	1,887.2	1,060.4	826.8
	Single Tank Conveyor	1,681.8	1,014.2	667.6
	Multi Tank Conveyor	2,002.8	1,039.9	962.9
High Temp	Under Counter	384.9	303.7	81.2
	Stationary Single Tank Door	1,700.8	1,173.4	527.4
	Single Tank Conveyor	1,638.6	1,318.4	320.2
	Multi Tank Conveyor	2,740.4	1,525.6	1,214.8
	Pot, Pan, and Utensil	922.9	764.7	158.2

Natural gas building and electric booster water heating

Dishwasher type		Therms _{Base}	Therms _{ESTAR}	ΔTherms
Low Temp	Under Counter	416.4	286.5	130.0
	Stationary Single Tank Door	1,887.2	1,060.4	826.8
	Single Tank Conveyor	1,681.8	1,014.2	667.6
	Multi Tank Conveyor	2,002.8	1,039.9	962.9
High Temp	Under Counter	262.4	207.0	55.4
	Stationary Single Tank Door	1,159.3	799.8	359.5
	Single Tank Conveyor	1,116.9	898.7	218.3
	Multi Tank Conveyor	1,868.0	1,039.9	828.1
	Pot, Pan, and Utensil	629.1	521.2	107.8

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an ENERGY STAR high-temperature, under counter dishwasher with gas building and gas booster water heating with defaults from the calculation above and the table within the electric energy savings characterization would save:

$$\begin{aligned} \Delta\text{PeakTherms} &= 81.2 / 365.25 \\ &= 0.2223 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta\text{Water} = (\text{WaterUse}_{\text{Base}} * \text{RacksWashed} * \text{Days}) - (\text{WaterUse}_{\text{ESTAR}} * \text{RacksWashed} * \text{Days})$$

Where:

$\text{WaterUse}_{\text{Base}}$ = Water use per rack (gal) of baseline dishwasher
 = Use value from table within the electric energy savings characterization as determined by machine type and sanitation method

$\text{WaterUse}_{\text{ESTAR}}$ = Water use per rack (gal) of ENERGY STAR dishwasher
 = Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

Other variables as defined above.

For example, an ENERGY STAR low-temperature, under counter dishwasher with defaults from the calculation above and the table within the electric energy savings characterization would save:

$$\begin{aligned} \Delta\text{Water} &= (\text{WaterUse}_{\text{Base}} * \text{RacksWashed} * \text{Days}) - (\text{WaterUse}_{\text{ESTAR}} * \text{RacksWashed} * \text{Days}) \\ \Delta\text{Water} &= (1.73 * 75 * 365.25) - (1.19 * 75 * 365.25) \\ &= 14,792.6 \text{ gallons} \end{aligned}$$

Savings for all dishwasher types are presented in the table below.

	Annual Water Consumption (gallons)		
	Baseline	ENERGY STAR	Savings
Low Temperature			
Under Counter	47,391.2	32,598.6	14,792.6
Stationary Single Tank Door	214,767.0	120,678.6	94,088.4
Single Tank Conveyor	191,391.0	115,419.0	75,972.0
Multi Tank Conveyor	227,916.0	118,341.0	109,575.0
High Temperature			
Under Counter	29,859.2	23,558.6	6,300.6
Stationary Single Tank Door	131,928.3	91,020.3	40,908.0
Single Tank Conveyor	127,107.0	102,270.0	24,837.0
Multi Tank Conveyor	212,575.5	118,341.0	94,234.5
Pot, Pan, and Utensil	71,589.0	59,316.6	12,272.4

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-DISH-V03-220101

SUNSET DATE: 1/1/2024*

* 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.

3.6.2. Commercial Solid and Glass Door Refrigerators & Freezers

DESCRIPTION

This measure applies to ENERGY STAR vertical closed and horizontal closed refrigerators or freezers installed in a commercial kitchen. ENERGY STAR commercial refrigerators and freezers are more energy efficient because they are designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors, which will significantly reduce energy consumption.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new ENERGY STAR certified vertical closed or horizontal closed, solid or glass door refrigerator or freezer, chef base or service over the counter meeting energy consumptions requirements as determined by door type (solid or glass) and refrigerated volume (V) or Total Display Area (sq ft).

ENERGY STAR Requirements (Version 5.0, Effective December 22, 2022)

Volume (ft ³)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
<i>Solid Door</i>		
0 < V < 15	≤ 0.0267V+0.8	≤ 0.21V+0.90
15 ≤ V < 30	≤ 0.05V+0.45	≤ 0.12V+2.248
30 ≤ V < 50		≤ 0.2578V-1.8864
V ≥ 50	≤ 0.025V+1.6991	≤ 0.14V+4.0
<i>Glass Door</i>		
0 < V < 15	≤ 0.095V+0.445	≤ 0.232V+2.36
15 ≤ V < 30	≤ 0.05V+1.12	
30 ≤ V < 50	≤ 0.076V+0.34	
V ≥ 50	≤ 0.105V-1.111	
Horizontal Closed		
<i>Solid or Glass Doors</i>		
All Volumes	≤ 0.05V+0.28	≤ 0.057V+0.55
Chef Bases		
<i>Doors or Drawers</i>		
All Volumes	≤ 0.05V+2.1	≤ 0.22V+6.0
Service Over Counter		
Total Display Area (in sq ft)		
0 < TDA < 20	≤ 0.32TDA+0.6	N/A
20 ≤ V < 40	≤ 0.65TDA-6.0	
40 ≤ V	≤ 0.4667TDA+1.3333	

DEFINITION OF BASELINE EQUIPMENT

Iowa Energy Efficiency Statewide Technical Reference Manual –3.6.2 Commercial Solid and Glass Door Refrigerators & Freezers

The baseline equipment is a new vertical closed or horizontal closed, solid or glass door refrigerator or freezer, chef base or service over the counter refrigerator that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶²²

DEEMED MEASURE COST

The incremental capital per cubic foot cost for this measure can be found below.⁶²³

Description and Volume (cu. ft.)	Refrigerator	Freezer
	Incremental Unit Cost per Foot	
<i>Solid Door</i>		
0 ≤ V < 15	\$24.21	\$30.41
15 ≤ V < 30		
30 ≤ V < 50		
50 ≤ V		
<i>Glass Door</i>		
0 ≤ V < 15	\$24.77	\$33.01
15 ≤ V < 30		
30 ≤ V < 50		
50 ≤ V		
Chest		
<i>Solid/Glass</i>	\$57.11	\$75.90
Chef Bases⁶²⁴		
<i>All Volumes</i>	\$57.11	\$75.90
Service Over the Counter – cost per square foot⁶²⁵		
<i>All Areas</i>	\$ 96.57	N/A

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

⁶²²Measure life from Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which is sourced from the California Public Utilities Commission (CPUC), Energy Division. DEER, 2014.

⁶²³ Northwest Regional Technical Forum, ENERGY STAR Version 4.0 Analysis. Refer to CostData&Analysis tab in ComRefrigeratorFreezer_v4_3.xlsm.

⁶²⁴ Currently no Qualified Products on the QPL and the V5.0 Data Package did not contain incremental cost data for this measure. New to ENERGY STAR standards, under review for addition to Federal Standards.

⁶²⁵ Cost from the ENERGY STAR V5.0 Commercial Refrigeration and Freezer Data Package (2022).

Iowa Energy Efficiency Statewide Technical Reference Manual –3.6.2 Commercial Solid and Glass Door Refrigerators & Freezers

Custom calculation below.⁶²⁶

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

Where:

kWh_{Base} = Maximum daily energy consumption (kWh/day) of baseline refrigerator or freezer
 = Calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWh_{Base} ⁶²⁷
Solid Door Refrigerator	$0.05V+1.36$
Glass Door Refrigerator	$0.1V+0.86$
Solid Door Freezer	$0.22V+1.38$
Glass Door Freezer	$0.29V+2.95$
Solid Door Chest Refrigerator	$0.05V+0.91$
Glass Door Chest Refrigerator	$0.06V+0.37$
Solid Door Chest Freezer	$0.06V + 1.12$
Glass Door Chest Freezer	$0.08V+1.23$

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR refrigerator or freezer
 = Custom or if unknown, calculated as shown in the table below using the actual refrigerated volume (V).⁶²⁸

Volume (ft ³)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
<i>Solid Door</i>		
$0 < V < 15$	$\leq 0.0267V+0.8$	$\leq 0.21V+0.90$
$15 \leq V < 30$	$\leq 0.05V+0.45$	$\leq 0.12V+2.248$
$30 \leq V < 50$		$\leq 0.2578V-1.8864$
$V \geq 50$	$\leq 0.025V+1.6991$	$\leq 0.14V+4.0$
<i>Glass Door</i>		
$0 < V < 15$	$\leq 0.095V+0.445$	$\leq 0.232V+2.36$
$15 \leq V < 30$	$\leq 0.05V+1.12$	
$30 \leq V < 50$	$\leq 0.076V+0.34$	
$V \geq 50$	$\leq 0.105V-1.111$	
Horizontal Closed		
<i>Solid or Glass Doors</i>		

⁶²⁶ Algorithms and assumptions from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021 and ENERGY STAR V5.0 Commercial Refrigerator and Freezer Data Package (2022).

⁶²⁷ United States Department of Energy, 10 CFR Part 431, “Energy Conservation Standards for Commercial Refrigeration Equipment”, March, 2017.

⁶²⁸ ENERGY STAR, “ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers”, v5.0, Effective December 22, 2022.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.6.2 Commercial Solid and Glass Door Refrigerators & Freezers

All Volumes	$\leq 0.05V+0.28$	$\leq 0.057V+0.55$
Chef Bases		
<i>Doors or Drawers</i>		
All Volumes	$\leq 0.05V+2.1$	$\leq 0.22V+6.0$
Service Over Counter		
Total Display Area (in sq ft)		
$0 < TDA < 20$	$\leq 0.32TDA+0.6$	N/A
$20 \leq V < 40$	$\leq 0.65TDA-6.0$	
$40 \leq V$	$\leq 0.4667TDA+1.3333$	

- V = Refrigerated volume (ft³) calculated in accordance with the Department of Energy test procedure in 10 CFR §431.64
- = Actual installed
- Days = Days of refrigerator or freezer operation per year
- = 365 days per year

For example, an ENERGY STAR solid door, vertical closed refrigerator with a volume of 35 ft³ would save:

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

$$\Delta kWh = [(0.05 * 35 + 1.36) - (0.05 * 35 + 0.45)] * 365$$

$$= 332.2 kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh / HOURS) * CF$$

Where:

- ΔkWh = Electric energy savings, calculated above
- HOURS = Hours of refrigerator or freezer operation per year
- = 8760⁶²⁹
- CF = Summer peak coincidence factor
- = 96.4%

For example, an ENERGY STAR solid door, vertical closed refrigerator with a volume of 35 ft³ would save:

$$\Delta kW = (332.2 / 8760) * 0.964$$

$$= 0.0366kW$$

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

⁶²⁹ Equipment is assumed to operate continuously, 24 hour per day, 365 days per year

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-CSGD-V02-230101

SUNSET DATE: 1/1/2026

3.6.3. Pre-Rinse Spray Valve

DESCRIPTION

Pre-rinse valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. More efficient spray valves use less water thereby reducing water consumption, water heating cost, and wastewater (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The primary impacts of this measure are water savings. Reduced hot water consumption saves either natural gas or electricity, depending on the type of energy the hot water heater uses.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new pre-rinse spray valve with a maximum flow rate that meets program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment flow rate depends on program type. For TOS, the baseline equipment is a new pre-rinse spray valve with a maximum flow rate of 1.20 gpm or less.⁶³⁰ For DI, the baseline equipment is an existing pre-rinse spray valve with a flow rate of 1.6 gpm or less.⁶³¹

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 5 years.⁶³²

DEEMED MEASURE COST

For TOS programs, the incremental cost of this measure is assumed to be \$0.⁶³³ For DI programs, the total installed cost is assumed to be \$53.⁶³⁴

LOADSHAPE

Loadshape NREW12 - Nonresidential Electric Hot Water – Restaurant

Loadshape NRGW12 - Nonresidential Gas Hot Water – Restaurant

⁶³⁰ Baseline for TOS programs is calculated using the maximum flow rate for each product class in 10 CFR 431.266, Energy Efficiency Program for Certain Commercial and Industrial Equipment weighted by estimated 2019 shipments for each product class from Table 3.6.1: U.S. DOE, “Final Determination Technical Support Document: Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Commercial Prerinse Spray Valves,” May 2022.

⁶³¹ Code of Federal Regulations, Energy Conservation Standards 10 CFR § 431.266 (a) From January 1, 2006 through January 28, 2019 the code set the maximum flow rate of 1.6 gallons per minute.

⁶³² Measure life from U.S. DOE, “Final Determination Technical Support Document: Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Commercial Prerinse Spray Valves,” May 2022, page 8-12.

⁶³³ Incremental measure cost based on U.S. DOE, “Final Determination Technical Support Document: Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Commercial Prerinse Spray Valves,” May 2022, page 8-1.

⁶³⁴ Total installed cost is the manufacturer selling price (\$34.99) from Table 8.2.1 multiplied by the retailer markup (1.52) from Table 8.2.2: U.S. DOE, “Final Determination Technical Support Document: Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Commercial Prerinse Spray Valves,” May 2022. It is assumed that programs typically install spray valves only when other kitchen equipment is also being installed, and therefore, there are no additional labor costs associated with spray valve installations.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 1,167.0 kWh for TOS and 3,112.0 kWh for DI.⁶³⁵

$$\Delta kWh = HotPercentage * (T_{out} - T_{in}) * 1.0 * 8.33 / Eff_{Heater} / 3,412 * \Delta WaterUse$$

Where:

- HotPercentage = Percentage of hot water used for rinse
= Custom or If unknown, use 100%
- T_{out} = Unmixed Outlet Water Temperature from the DHW system
= Actual, otherwise assume 140.⁶³⁶
- T_{in} = Inlet Water Temperature to the DHW system
= Actual, otherwise assume 56.5.⁶³⁷
- 1.0 = Specific heat of water (Btu/lb/°F)
- 8.33 = Specific weight capacity of water (lb/gal)
- Eff_{Heater} = Efficiency of water heater
= Custom or if unknown, use 98% for electric water heaters
- 3,412 = kWh to Btu conversion factor
- ΔWaterUse = Change in annual water consumption
= Custom calculation in Water Impact Descriptions and Calculation section of this measure, otherwise use 5,610.2 gal/yr for TOS and 14,960.6 gal/yr for DI

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above, would save:

$$\begin{aligned} \Delta kWh &= 1.00 * (140 - 56.5) * 1.0 * 8.33 / 0.98 / 3,412 * 5,610.2 \\ &= 1,167.0 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / ((Minutes/60) * Days) * CF$$

Where:

⁶³⁵ Algorithms and assumptions except for water temperature values flow rates, and specific weight of water derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016. See file Pre Rinse Spray Valve Calculations_04082021.xlsx.

⁶³⁶ Ideally the actual set point of the water heater should be used. If not, 140 degrees is provided as an estimate based on review of building and plumbing codes for IA. The codes limit temperatures at the end use but not at the water heater system, which can be anywhere in the range 120 -201 degrees. Generally speaking, code limits the temperature to fixtures to 120 degrees F and 140 degrees for applications like laundry or dishwashing.

⁶³⁷ Averaged monthly water main temperature calculated using the methodology provided in Building America Research Benchmark Definition, updated December 2009. Pg.19-20. <http://www.nrel.gov/docs/fy10osti/47246.pdf>; water main temperature represents the average of TMY3 data from all Class I stations located in Des Moines, IA.

ΔkWh	= Electric energy savings, calculated above
Minutes	= Average daily minutes of spray valve operation = Custom or if unknown, use 64 minutes per day. ⁶³⁸
60	= Minutes to hours conversion factor
Days	= Annual days of operation = Custom or if unknown, use 365.25 days per year
CF	= Summer peak coincidence factor = 1.14% for a fast-food restaurant and 2.50% for a sit-down restaurant. ⁶³⁹

For example, an efficient pre-rinse spray valve installed in a sit-down restaurant under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned} \Delta kW &= 1,167.0 / ((64/60) * 365.25) * 0.0250 \\ &= 0.07488 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 49.2 therms/yr for TOS and 131.3 therms/yr for DI.⁶⁴⁰

$$\Delta Therms = HotPercentage * (T_{out} - T_{in}) * 1.0 * 8.33 / Eff_{Heater} / 100,000 * \Delta WaterUse$$

Where:

Eff_{Heater} = Efficiency of water heater
= Custom or if unknown, use 78%⁶⁴¹ for gas water heaters

100,000 = Btu to therms conversion factor

Other variables as defined above.

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned} \Delta Therms &= 1.00 * (140 - 56.5) * 1.0 * 8.2 / 0.78 / 100,000 * 5,610.2 \\ &= 49.2 \\ &\text{therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

⁶³⁸ ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016

⁶³⁹ CF adopted from Low Flow Faucet Aerator measure, calculated as follows: Assumptions for percentage of usage during peak period (2-6pm) were made and then multiplied by 65/365 (65 being the number of days in peak period) and by the number of total annual recovery hours to give an estimate of the number of hours of recovery during peak periods. There are 260 hours in the peak period, so the probability there will be savings during the peak period is calculated as the number of hours of recovery during peak divided by 260. See 'Commercial Faucet Aerator Calculations.xls' for details.

⁶⁴⁰ Algorithms and assumptions derived except for water temperature values, flow rates, specific weight of water, and gas water heater efficiency from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016. See file Pre Rinse Spray Valve Calculations_04082021.xlsx

⁶⁴¹ 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%.

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

$\Delta Therms$ = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned} \Delta PeakTherms &= 49.2 / 365.25 \\ &= 0.1347 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below, otherwise use deemed value of 5,844.0 gal/yr for TOS and 14,493.1 gal/yr for DI.⁶⁴²

$$\Delta WaterUse = (Flow_{Base} - Flow_{EE}) * Minutes * Days$$

Where:

$Flow_{Base}$ = Flow rate (gal/min) of baseline pre-rinse spray valve
 = Custom or if unknown, use 1.20 gpm for TOS⁶⁴³ and 1.6 gpm for DI⁶⁴⁴

$Flow_{EE}$ = Flow rate (gal/min) of efficient pre-rinse spray valve
 = Custom or if unknown, use 0.96 gal/min⁶⁴⁵

Other variables as defined above.

For example, an efficient pre-rinse spray valve, installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned} \Delta WaterUse &= (1.20 - 0.96) * 64 * 365.25 \\ &= 5,610.24 \text{ gal/yr} \end{aligned}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-SPRY-V05-240101

SUNSET DATE: 1/1/2028

⁶⁴² Algorithms and assumptions, except for flow rates, derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated October 2016. See file Pre Rinse Spray Valve Calculations_04082021.xlsx.

⁶⁴³ Baseline for TOS programs is calculated using the maximum flow rate for each product class in 10 CFR 431.266, Energy Efficiency Program for Certain Commercial and Industrial Equipment weighted by estimated 2018 shipments for each product class from Table 3.6.1: U.S. DOE, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Prerinse Spray Valves," December 2015.

⁶⁴⁴ Code of Federal Regulations, Energy Conservation Standards 10 CFR § 431.266 (a) From January 1, 2006 through January 28, 2019 the code set the maximum flow rate of 1.6 gallons per minute.

⁶⁴⁵ A new pre-rinse spray valve is assumed to be 20% more efficient than the federal standard.

3.6.4. Infrared Upright Broiler

DESCRIPTION

This measure applies to new natural gas fired high efficiency upright broilers utilizing infrared burners and installed in a commercial kitchen. Upright broilers are heavy-duty, freestanding overfired broilers. Infrared broilers move heat faster and carry a higher heat intensity than non-infrared broilers.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new natural gas upright broiler with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new natural gas upright broiler without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.⁶⁴⁶

DEEMED MEASURE COST

The incremental capital cost for this measure is \$5,900.⁶⁴⁷

LOADSHAPE

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 2.7 therms / MBtu/hr input.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours) / 100,000}{InputRate_{EE} / 1,000}$$

Where:

$InputRate_{Base}$ = Rated energy input rate of baseline upright broiler (Btu/hr)

⁶⁴⁶Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

⁶⁴⁷Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

	= 95,000 Btu/hr ⁶⁴⁸
InputRate _{EE}	= Rated energy input rate of infrared upright broiler (Btu/hr) = Custom or if unknown, use 82,333 Btu/hr ⁶⁴⁹
Duty	= Duty cycle of upright broiler (%) = Custom or if unknown, use 70% ⁶⁵⁰
Hours	= Typical operating hours of upright broiler = Custom or if unknown, use 2,496 hours ⁶⁵¹
100,000	= Btu to therms conversion factor
1,000	= Btu to Mbtu conversion factor

For example, an infrared upright broiler with default values from the algorithm above would save:

$$\Delta\text{Therms} = [(95,000 - 82,333) * (0.70 * 2,496) / 100,000] / (82,333 / 1,000)$$

$$= 2.7 \text{ therms/ MBtu/hr input}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms	= Natural gas energy savings, calculated above
Days	= Annual days of operation = Custom or if unknown, use 312 days per year ⁶⁵²

For example, an infrared upright broiler with default values from the calculation above would save:

$$\Delta\text{PeakTherms} = 2.7 / 312$$

$$= 0.0087 \text{ therms/MBtu/hr input/day}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IRUB-V01-170101

⁶⁴⁸ Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Table 4.3
http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

⁶⁴⁹ Infrared energy input rate calculated based on baseline energy input rate of 95,000 Btu/hr, baseline cooking efficiency of 30%, and infrared cooking efficiency of 34%

⁶⁵⁰ Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

⁶⁵¹ Typical operating hours based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3

⁶⁵² Based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3

SUNSET DATE: 1/1/2022*

* 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.

3.6.5. Infrared Salamander Broiler

DESCRIPTION

This measure applies to new natural gas fired high efficiency salamander broilers utilizing infrared burners installed in a commercial kitchen. Salamander broilers are medium-input overfired broilers that are typically mounted on the backshelf of a range. Infrared broilers move heat faster and carry a higher heat intensity than non-infrared broilers.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new natural gas fired salamander broiler with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new natural gas fired salamander broiler without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁵³

DEEMED MEASURE COST

The incremental capital cost for this measure is \$1,000.⁶⁵⁴

LOADSHAPE

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 9.7 therms / MBtu/hr input.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours) / 100,000}{InputRate_{EE} / 1,000}$$

Where:

$InputRate_{Base}$ = Rated energy input rate of baseline salamander broiler (Btu/hr)

⁶⁵³Measure life from Nicor Gas Energy Efficiency Plan 2022-2025. Revised Plan Filed March, 2021.

⁶⁵⁴Incremental cost from Nicor Gas Energy Efficiency Plan 2022-2025. Revised Plan Filed March, 2021.

	= 38,500 Btu/hr ⁶⁵⁵
InputRate _{EE}	= Rated energy input rate of infrared salamander broiler (Btu/hr) = Custom or if unknown, use 24,750 Btu/hr ⁶⁵⁶
Duty	= Duty cycle of salamander broiler (%) = Custom or if unknown, use 70% ⁶⁵⁷
Hours	= Typical operating hours of salamander broiler = Custom or if unknown, use 2,496 hours ⁶⁵⁸
100,000	= Btu to therms conversion factor
1,000	= Btu to Mbtu conversion factor

For example, an infrared salamander broiler with default values from the algorithm above would save:

$$\Delta\text{Therms} = [(38,500 - 24,750) * (0.70 * 2,496) / 100,000] / (24,750 / 1,000)$$

$$= 9.7 \text{ therms/ MBtu/hr input}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms	= Natural gas energy savings, calculated above
Days	= Annual days of operation = Custom or if unknown, use 312 days per year ⁶⁵⁹

For example, an infrared salamander broiler with default values from the calculation above would save:

$$\Delta\text{PeakTherms} = 9.7 / 312$$

$$= 0.0311 \text{ therms/MBtu/hr input/day}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

⁶⁵⁵ Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Table 4.3
http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

⁶⁵⁶ Calculated energy input rate based on baseline energy input rate of 38,500 Btu/hr, baseline cooking efficiency of 22.5%, and infrared cooking efficiency of 35%

⁶⁵⁷ Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

⁶⁵⁸ Typical operating hours based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3

⁶⁵⁹ Based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3

MEASURE CODE: NR-FSE-IRBL-V02-240101

SUNSET DATE: 1/1/2027

3.6.6. Infrared Charbroiler

DESCRIPTION

This measure applies to new natural gas fired charbroilers that utilize infrared burners installed in a commercial kitchen. Charbroilers cook food in a grid placed over a radiant heat source. Infrared broilers move heat faster and carry a higher heat intensity than non-infrared broilers.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new natural gas charbroiler with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new natural gas charbroiler without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁶⁰

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,200.⁶⁶¹

LOADSHAPE

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 8.4 therms / MBtu/hr input.⁶⁶²

$$\Delta Therms = [(\Delta PreheatEnergy + \Delta CookingEnergy) * Days / 100,000] / \left(\frac{InputRate_{EE}}{1,000} \right)$$

Where:

$$\Delta PreheatEnergy = (PreheatRate_{Base} * Preheats * PreheatTime / 60) - (PreheatRate_{EE} * Preheats * PreheatTime / 60)$$

⁶⁶⁰Measure life from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator, <https://caenergywise.com/calculators/natural-gas-conveyor-broilers/#calc>

⁶⁶¹Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562

⁶⁶² Assumptions derived from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment, http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

$$\text{PreheatTime} / 60)$$

$$\Delta\text{CookingEnergy} = (\text{InputRate}_{\text{Base}} - \text{InputRate}_{\text{EE}}) * \text{Hours}$$

Where:

- Days = Annual days of operation
= Custom or if unknown, use 312 days per year⁶⁶³
- 100,000 = Btu to therms conversion factor
- 1,000 = Btu to MBtu conversion factor
- PreheatRate_{Base} = Preheat energy rate of baseline charbroiler
= 64,000 Btu/hr
- PreheatRate_{EE} = Preheat energy rate of infrared charbroiler
= Custom or if unknown, use 54,000 Btu/hr
- Preheats = Number of preheats per day
= Custom or if unknown, use 1 preheat per day
- PreheatTime = Length of one preheat
= Custom or if unknown, use 15 minutes per preheat⁶⁶⁴
- 60 = Minutes to hours conversion factor
- InputRate_{Base} = Input energy rate of baseline charbroiler
= 128,000 Btu/hr
- InputRate_{EE} = Input energy rate of infrared charbroiler
= Custom or if unknown, use 96,000 Btu/hr
- Hours = Average daily hours of operation
= Custom or if unknown, use 8 hours per day

For example, an infrared charbroiler with default values from the calculation above would save:

$$\Delta\text{Therms} = [(\Delta\text{PreheatEnergy} + \Delta\text{CookingEnergy}) * \text{Days} / 100,000] / (\text{InputRate}_{\text{EE}}/1,000)$$

Where:

$$\begin{aligned} \Delta\text{PreheatEnergy} &= (64,000 * 1 * 15 / 60) - (54,000 * 1 * 15 / 60) \\ &= 2,500 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (128,000 - 96,000) * 8 \\ &= 256,000 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= [(2,500 + 256,000) * 312 / 100,000] / (96,000/1,000) \\ &= 8.4 \text{ therms/ MBtu/hr input} \end{aligned}$$

PEAK GAS SAVINGS

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

⁶⁶³Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3

⁶⁶⁴Typical preheat time from FSTC Broiler Technology Assessment

Where:

Δ Therms = Natural gas energy savings, calculated above

Other variables as defined above.

For example, an infrared charbroiler with default values from the calculation above would save:

$$\begin{aligned}\Delta\text{PeakTherms} &= 8.4 / 312 \\ &= 0.0269 \text{ therms/MBtu/hr input/day}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IRCB-V01-170101

SUNSET DATE: 1/1/2022*

* 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.

3.6.7. Convection Oven

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR convection ovens installed in a commercial kitchen. Convection ovens are general purpose ovens that use fans to circulate hot, dry air over the food surface. ENERGY STAR certified convection ovens are approximately 20% more efficient than standard ovens.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR certified convection oven meeting idle energy rate (kW or Btu/hr) and cooking efficiency (%) limits, as determined by both fuel type and oven capacity (full size versus half size).

ENERGY STAR Requirements (Version 3.0, Effective January 1, 2023)

Oven Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate (kW)	Cooking Efficiency %	Idle Energy Rate (Btu/h)	Cooking Efficiency %
Full Size - All # pans	N/A	N/A	≤ 9,500	≥ 49
Half-Size	≤ 1.00	≥ 71	N/A	N/A
Full-Size ≥ 5 Pans	≤ 1.40	≥ 76	N/A	N/A
Full-Size < 5 Pans	≤ 1.00		N/A	

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas convection oven that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁶⁵

DEEMED MEASURE COST

The incremental capital cost for this measure is \$400.⁶⁶⁶

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

⁶⁶⁵ Lifetime from ENERGY STAR V3.0 Commercial Ovens Data Package (2022), which is sourced from the CA TRM and CA Energy Wise.

⁶⁶⁶ Measure cost from 2014-2023 Iowa Statewide Assessment of Energy Efficiency Potential

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric convection oven below, otherwise use deemed value of an average of 3,777 kWh for full-size ovens (2,982 kWh for models with at least 5 pans, 4,573 kWh for models with less than 5 pans) and 192.1 kWh for half-size ovens.⁶⁶⁷

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = (IdleRate_{Base} * (Hours - FoodCooked / Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked / Production_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * EFOOD / Eff_{Base}) - (FoodCooked * EFOOD / Eff_{ESTAR})$$

Where:

- Hours = Average daily hours of operation
= Custom or if unknown, use 12 hours per day
- Days = Annual days of operation
= Custom or if unknown, use 365.25 days per year
- 1,000 = Wh to kWh conversion factor
- FoodCooked = Food cooked per day
= Custom or if unknown, use 100 pounds
- Production_{Base} = Production capacity of baseline electric convection oven
= 90 lb/hr for full-size ovens and 45 lb/hr for half-size ovens
- Production_{ESTAR} = Production capacity of ENERGY STAR electric convection oven
= Custom or if unknown, use 90 lb/hr for full-size ovens and 50 lb/hr for half-size ovens
- IdleRate_{Base} = Idle energy rate of baseline electric convection oven
= 2,000 W for full-size ovens and 1,030 W for half-size ovens
- IdleRate_{ESTAR} = Idle energy rate of ENERGY STAR electric convection oven
= Custom or if unknown, use 1,400 for full-size ovens, greater than or equal to 5 pans, and 1,000 for half-size ovens and full-size ovens, less than 5 pans.
- EFOOD = ASTM energy to food
= 73.2 Wh/lb
- Eff_{Base} = Cooking efficiency of baseline electric convection oven
= 65% for full-size ovens and 68% for half-size ovens
- Eff_{ESTAR} = Cooking efficiency of ENERGY STAR electric convection oven
= Custom or if unknown, use 71% for half-size ovens and 76% for full-size ovens

⁶⁶⁷ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, updated July 15, 2021, as well as the ENERGY STAR v3.0 Commercial Ovens Data Packet (2022).

For example, an ENERGY STAR full-size electric convection oven, with greater than 5 pans, with default values from the algorithm above would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= (2,000 * (12 - 100 / 90)) - (1,400 * (12 - 100 / 90)) \\ &= 6,533 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 73.2 / 0.65) - (100 * 73.2 / 0.76) \\ &= 1,630 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (6,533 + 1,630) * 365.25 / 1,000 \\ &= 2,982 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
= 78.7%

Other variables as defined above.

For example, an ENERGY STAR full-size electric convection oven with default values from the algorithm above would save:

$$\begin{aligned} \Delta kW &= 2,982 / (12 * 365.25) * 0.787 \\ &= 0.8644 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas convection oven below, otherwise use deemed value of 240.5 therms/yr.⁶⁶⁸

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\Delta IdleEnergy = (IdleRate_{Base} * (Hours - FoodCooked / Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked / Production_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

100,000 = Btu to therms conversion factor

FoodCooked = Food cooked per day
= Custom or if unknown, use 100 pounds

Production_{Base} = Production capacity of baseline gas convection oven
= 83 lb/hr

⁶⁶⁸ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, updated July 15, 2021, as well as the ENERGY STAR v3.0 Commercial Ovens Data Packet (2022).

- Production_{ESTAR} = Production capacity of ENERGY STAR gas convection oven
= Custom or if unknown, use 86 lb/hr
- IdleRate_{Base} = Idle energy rate of baseline gas convection oven
= 15,100 Btu/hr
- IdleRate_{ESTAR} = Idle energy rate of ENERGY STAR gas convection oven
= Custom or if unknown, use 9,500 Btu/hr
- EFOOD = ASTM energy to food
= 250 Btu/lb
- Eff_{Base} = Cooking efficiency of baseline gas convection oven
= 44%
- Eff_{ESTAR} = Cooking efficiency of ENERGY STAR gas convection oven
= Custom or if unknown, use 49%

Other variables as defined above.

For example, an ENERGY STAR gas convection oven with default values from the algorithm above would save:

$$\Delta\text{Therms} = (\Delta\text{IdleEnergy} + \Delta\text{CookingEnergy}) * \text{Days} / 100,000$$

Where:

$$\begin{aligned} \Delta\text{IdleEnergy} &= (15,100 * (12 - 100 / 83)) - (9,500 * (12 - 100 / 86)) \\ &= 60,054 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (100 * 250 / 0.44) - (100 * 250 / 0.49) \\ &= 5,798 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= (60,054 + 5,798) * 365.25 / 100,000 \\ &= 240.5 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

$$\Delta\text{Therms} = \text{Natural gas energy savings, calculated above}$$

Other variables as defined above.

For example, an ENERGY STAR gas convection with default values from the algorithm above would save:

$$\begin{aligned} \Delta\text{PeakTherms} &= 240.5 / 365.25 \\ &= 0.6585 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-ESCV-V02-230101

SUNSET DATE: 1/1/2027

3.6.8. Conveyor Oven

DESCRIPTION

This measure applies to a natural gas fired high efficiency conveyor oven installed in a commercial kitchen.

Conveyor ovens are available using four different heating processes: infrared, natural convection with a ceramic baking hearth, forced convection or air impingement, or a combination of infrared and forced convection. Conveyor ovens are typically used for producing a limited number of products with similar cooking requirements at high production rates.

Some manufacturers offer an air-curtain feature at either end of the cooking chamber that helps to keep the heated air inside the conveyor oven. The air curtain operates as a virtual oven wall and helps reduce both the idle energy of the oven and the resultant heat gain to the kitchen.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a natural gas conveyor oven with cooking efficiency and idle energy rates that meet the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new, standard, natural gas conveyor oven.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁶⁹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$1800.⁶⁷⁰

LOADSHAPE

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

⁶⁶⁹Measure life from Food Service Technology Center Gas Conveyor Oven Life-Cycle Cost Calculator <https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc>. This calculator is supported by the Pacific Gas & Electric Company Work Paper PGECOFST117 "Commercial Conveyor Oven - Gas", May 2014.

⁶⁷⁰ Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 633.9 therms/yr.⁶⁷¹

$$\Delta Therms = (\Delta PreheatEnergy + \Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\Delta PreheatEnergy = (PreheatEnergy_{Base} * Preheats) - (PreheatEnergy_{EE} * Preheats)$$

$$\Delta IdleEnergy = IdleRate_{Base} * (Hours - (FoodCooked / Production_{Base}) - (Preheats * PreheatTime / 60)) - IdleRate_{EE} * (Hours - (FoodCooked / Production_{EE}) - (Preheats * PreheatTime / 60))$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{EE})$$

Where:

Days = Annual days of operation
 = Custom or if unknown, use 312 days per year⁶⁷²

100,000 = Btu to therms conversion factor

PreheatEnergy_{Base} = Preheat energy of baseline oven
 = 35,000 Btu

PreheatEnergy_{EE} = Preheat energy of efficient oven
 = Custom or if unknown, use 18,000 Btu

Preheats = Number of preheats per day
 = Custom or if unknown, use 1 preheat per day

PreheatTime = Length of one preheat
 = Custom or if unknown, use 15 minutes per preheat

60 = Minutes to hours conversion factor

IdleRate_{Base} = Idle energy rate of baseline oven
 = 70,000 Btu/hr

IdleRate_{EE} = Idle energy rate of efficient oven
 = Custom or if unknown, use 57,000 Btu/hr

Hours = Average daily hours of operation
 = Custom or if unknown, use 10 hours per day⁶⁷³

FoodCooked = Number of pizzas cooked per day
 = Custom or if unknown, use 250 pizzas per day

Production_{Base} = Production capacity of baseline oven
 = 150 pizzas per hour

⁶⁷¹ Unless otherwise noted, the assumptions are derived from the Food Service Technology Center Gas Conveyor Oven Life-Cycle Cost Calculator, supported by the Pacific Gas & Electric Company Work Paper PGECOFST117 "Commercial Conveyor Oven - Gas", May 2014, pg. 6.

⁶⁷² Assumptions are derived from the FSTC Oven Technology Assessment.

⁶⁷³ Ibid.

- Production_{EE} = Production capacity of efficient oven
= Custom or if unknown, use 220 pizzas per hour
- E_{FOOD} = ASTM energy to food
= 190 Btu/pizza
- Eff_{Base} = Cooking efficiency of baseline oven
= 20%
- Eff_{EE} = Cooking efficiency of efficient oven
= Custom or if unknown, use 42%

For example, an efficient conveyor oven with default values from the algorithm above would save:

$$\Delta\text{Therms} = (\Delta\text{PreheatEnergy} + \Delta\text{IdleEnergy} + \Delta\text{CookingEnergy}) * \text{Days} / 100,000$$

Where:

$$\begin{aligned} \Delta\text{PreheatEnergy} &= (35,000 * 1) - (18,000 * 1) \\ &= 17,000 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{IdleEnergy} &= 70,000 * (10 - (250 / 150) - (1 * 15 / 60)) - 57,000 * (10 - (250 / 220) - (1 * 15 / 60)) \\ &= 74,856 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (250 * 190 / 0.20) - (250 * 190 / 0.42) \\ &= 124,405 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= (17,000 + 74,856 + 124,405) * 312 / 100,000 \\ &= 674.7 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms = Natural gas energy savings, calculated above

Days = Annual days of operation
= Custom or if unknown, use 312 days per year

For example, an efficient conveyor oven with default values from the algorithm above would save:

$$\begin{aligned} \Delta\text{PeakTherms} &= 674.7 / 312 \\ &= 2.163 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-CVOV-V05-220101

SUNSET DATE: 1/1/2025

3.6.9. Infrared Rotisserie Oven

DESCRIPTION

This measure applies to new natural gas fired high efficiency rotisserie ovens utilizing infrared burners and installed in a commercial kitchen. Rotisserie ovens are designed for batch cooking, with individual spits arranged on a rotating wheel or drum within an enclosed cooking cavity. Infrared ovens move heat faster and carry a higher heat intensity than non-infrared ovens.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new natural gas rotisserie oven with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new natural gas rotisserie oven without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁷⁴

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,700.⁶⁷⁵

LOADSHAPE

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 3.6 therms / MBtu/hr input.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours) / 100,000}{InputRate_{EE} / 1,000}$$

Where:

⁶⁷⁴Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

⁶⁷⁵Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

InputRate _{Base}	= Energy input rate of baseline rotisserie oven (Btu/hr) = 50,000 Btu/hr ⁶⁷⁶
InputRate _{EE}	= Energy input rate of infrared rotisserie oven (Btu/hr) = Custom or if unknown, use 40,323 Btu/hr ⁶⁷⁷
Duty	= Duty cycle of rotisserie oven (%) = Custom or if unknown, use 60% ⁶⁷⁸
Hours	= Typical operating hours of rotisserie oven = Custom or if unknown, use 2,496 hours ⁶⁷⁹
100,000	= Btu to therms conversion factor
1,000	= Btu to Mbtu conversion factor

For example, an infrared rotisserie oven with default values from the algorithm above would save:

$$\Delta\text{Therms} = [(50,000 - 40,323) * (0.60 * 2,496) / 100,000] / (40,323 / 1,000)$$

$$= 3.6 \text{ therms/ MBtu/hr input}$$

PEAK GAS SAVINGS

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

Where:

ΔTherms	= Natural gas energy savings, calculated above
Days	= Annual days of operation = Custom or if unknown, use 312 days per year ⁶⁸⁰

For example, an infrared rotisserie oven with default values from the calculation above would save:

$$\Delta\text{PeakTherms} = 3.6 / 312$$

$$= 0.0115 \text{ therms/MBtu/hr input/day}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

⁶⁷⁶ Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Table 7-2 .

⁶⁷⁷ Infrared energy input rate calculated based on baseline energy input rate of 50,000 Btu/hr, baseline cooking efficiency of 25%, and infrared cooking efficiency of 31%

⁶⁷⁸ Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7-2.

⁶⁷⁹ Typical operating hours based on oven operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Oven Technical Assessment, Table 7-2.

⁶⁸⁰ Based on oven operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Oven Technical Assessment, Table 7-2.

N/A

MEASURE CODE: NR-FSE-IROV-V02-220101

SUNSET DATE: 1/1/2025

3.6.10. Commercial Steam Cooker

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR steam cookers installed in a commercial kitchen. Commercial steam cookers contain compartments where steam energy is transferred to food by direct contact. ENERGY STAR certified steam cookers have shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficiency steam delivery.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR certified steam cooker meeting idle energy rate (kW or Btu/hr) and cooking efficiency (%) limits, as determined by both fuel type and pan capacity.

ENERGY STAR Requirements (Version 1.2, Effective August 1, 2003)

Pan Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
3-pan	≤ 400 W	≥ 50%	≤ 6,250 Btu/hr	≥ 38% N/A
4-pan	≤ 530 W		≤ 8,350 Btu/hr	
5-pan	≤ 670 W		≤ 10,400 Btu/hr	
6-pan and larger	≤ 800 W		≤ 12,500 Btu/hr	

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas steam cooker that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁸¹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,000 for electric steam cookers and \$1,000 for gas steam cookers.⁶⁸²

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRGC01 - Nonresidential Gas Cooking – Restaurant

⁶⁸¹Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021
https://www.energystar.gov/sites/default/files/asset/document/CFS_calculator_07-15-2021.xlsx

⁶⁸²Incremental costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021. Calculator cites EPA research using AutoQuotes, October 2020.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric steam cooker below, otherwise use deemed value from the table that follows.⁶⁸³

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [((1 - SteamMode) * IdleRate_{Base} + SteamMode * Production_{Base} * Pans * E_{FOOD} / Eff_{Base}) * (Hours - FoodCooked / (Production_{Base} * Pans))] - [((1 - SteamMode) * IdleRate_{ESTAR} + SteamMode * Production_{ESTAR} * Pans * E_{FOOD} / Eff_{ESTAR}) * (Hours - FoodCooked / (Production_{ESTAR} * Pans))]$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

- Days = Annual days of operation
= Custom or if unknown, use 365.25 days per year
- 1,000 = Wh to kWh conversion factor
- SteamMode = Time (%) in constant steam mode
= Custom or if unknown, use 40%
- IdleRate_{Base} = Idle energy rate (W) of baseline electric steam cooker
= Use value from table below as determined by pan capacity⁶⁸⁴
- IdleRate_{ESTAR} = Idle energy rate (W) of ENERGY STAR electric steam cooker
= Custom or if unknown, use value from table below as determined by pan capacity

Idle Energy Rates of Electric Steam Cooker		
Pan Capacity	IdleRate _{Base}	IdleRate _{ESTAR}
3	1,100	400
4		530
5		670
6		800
10		800

Production_{Base} = Production capacity (lb/hr) per pan of baseline electric steam cooker
= 23.3 lb/hr

Production_{ESTAR} = Production capacity (lb/hr) per pan of ENERGY STAR electric steam cooker
= Custom or if unknown, use 16.7 lb/hr

Pans = Number of pans per steam cooker

⁶⁸³ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

⁶⁸⁴ Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR for steam generator and boiler-based cookers

- = Custom or if unknown, use 6 pans
- EFOOD = ASTM energy to food
= 30.8 Wh/lb
- Eff_{Base} = Cooking efficiency (%) of baseline electric steam cooker⁶⁸⁵
= 30%
- Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR electric steam cooker
= Custom or if unknown, use 50%
- Hours = Average daily hours of operation
= Custom or if unknown, use 9hours per day
- FoodCooked = Food cooked per day (lbs)
= Custom or if unknown, use 100 pounds

For example, an ENERGY STAR, 6-pan electric steam cooker with defaults from the calculation above would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= [((1 - 0.40) * 1,100 + 0.40 * 23.3 * 6 * 30.8/0.30) * (9 - 100/(23.3 * 6))] - [((1 - 0.40) * 800 + 0.40 * 16.7 * 6 * 30.8/0.50) * (9 - 100/(16.7 * 6))] \\ &= 29,434 Wh \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 30.8/ 0.30) - (100 * 30.8/ 0.50) \\ &= 4,106.7 Wh \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (44,418 + 4,840) * 365.25 /1,000 \\ &= 12,250.7 kWh \end{aligned}$$

Savings for all pan capacities are presented in the table below.

Pan Capacity	Savings (kWh)
3	6,875.0
4	8,666.5
5	10,458.5
6	12,250.7
10	19,420.7
Average	11,534.3

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

- ΔkWh = Electric energy savings, calculated above
- CF = Summer peak coincidence factor
= 78.7%

Other variables as defined above

⁶⁸⁵ Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR for steam generator and boiler-based cookers

For example, an ENERGY STAR, 6-pan electric steam cooker with defaults from the calculation above would save:

$$\begin{aligned} \Delta kW &= 12,250.7 / (9 * 365.25) * 0.787 \\ &= 2.9329 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas steam cooker below, otherwise use deemed value from the table that follows.⁶⁸⁶

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= [((1 - SteamMode) * IdleRate_{Base} + SteamMode * Production_{Base} * Pans * E_{FOOD} / Eff_{Base}) * \\ & \quad (Hours - FoodCooked / (Production_{Base} * Pans))] - [((1 - SteamMode) * IdleRate_{ESTAR} + \\ & \quad SteamMode * Production_{ESTAR} * Pans * E_{FOOD} / Eff_{ESTAR}) * (Hours - \\ & \quad FoodCooked / (Production_{ESTAR} * Pans))] \end{aligned}$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

100,000 = Btu to therms conversion factor

IdleRate_{Base} = Idle energy rate (Btu/hr) of baseline gas steam cooker

= Use value from table below as determined by pan capacity⁶⁸⁷

IdleRate_{ESTAR} = Idle energy rate (Btu/hr) of ENERGY STAR gas steam cooker

= Custom or if unknown, use value from table below as determined by pan capacity

Idle Energy Rates of Gas Steam Cooker		
Pan Capacity	IdleRate _{Base}	IdleRate _{ESTAR}
3	16,500	6,250
5		10,400
6		12,500
10		12,500

Production_{Base} = Production capacity (lb/hr) per pan of baseline gas steam cooker

= 23.3 lb/hr

Production_{ESTAR} = Production capacity (lb/hr) per pan of ENERGY STAR gas steam cooker

= Custom or if unknown, use 20 lb/hr

E_{FOOD} = ASTM energy to food

= 105 Btu/lb

⁶⁸⁶ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

⁶⁸⁷ Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR for steam generator and boiler-based cookers

Eff_{Base} = Cooking efficiency (%) of baseline gas steam cooker⁶⁸⁸
 = 18%

Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR gas steam cooker
 = Custom or if unknown, use 38%

Other variables as defined above.

For example, an ENERGY STAR, 6-pan gas steam cooker with defaults from the calculation above would save:

$$\Delta\text{Therms} = (\Delta\text{IdleEnergy} + \Delta\text{CookingEnergy}) * \text{Days} / 100,000$$

Where:

$$\Delta\text{IdleEnergy} = [((1 - 0.40) * 16,500 + 0.40 * 23.3 * 6 * 105/0.18) * (9 - 100/(23.3 * 6))] - [((1 - 0.40) * 12,500 + 0.40 * 20 * 6 * 105/0.38) * (9 - 100/(20 * 6))]$$

$$= 182,699.3 \text{ Btu}$$

$$\Delta\text{CookingEnergy} = (100 * 105/ 0.18) - (100 * 105/ 0.38)$$

$$= 30,701.8 \text{ Btu}$$

$$\Delta\text{Therms} = (281,434 + 36,005) * 365.25 / 100,000$$

$$= 779.4 \text{ therms}$$

Savings for all pan capacities are presented in the table below.

Pan Capacity	Savings (Therms)
3	458.3
5	672.8
6	779.4
10	1,204.9
Average	778.8

PEAK GAS SAVINGS

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

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above

For example, an ENERGY STAR, 6-pan gas steam cooker with defaults from the calculation above would save:

$$\Delta\text{PeakTherms} = 779.4 / 365.25$$

$$= 2.1340 \text{ therms/day}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below.⁶⁸⁹ Savings are the same for electric and gas steam cookers.

$$\Delta\text{Water} = (\Delta\text{WaterUse}_{\text{Base}} - \Delta\text{WaterUse}_{\text{ESTAR}}) * \text{Hours} * \text{Days}$$

⁶⁸⁸ Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR for steam generator and boiler-based cookers

⁶⁸⁹ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

Where:

WaterUse_{Base} = Water use (gal/hr) of baseline steam cooker
 = 40 gal/hr

WaterUse_{ESTAR} = Water use (gal/hr) of ENERGY STAR steam cooker
 = Actual or if unknown, source from the following table:

Steam Cooker Type	Water Use (gallons/hour)
Steam Generator	15
Boiler Based	10
Boilerless	3
Unknown	9.3 ⁶⁹⁰

Other variables as defined above

For example, a steam cooker with defaults from the calculation above would save

$$\begin{aligned} \Delta\text{WaterUse} &= (40 - 9.315) * 9 * 365 \\ &= 100,849.582,181 \text{ gal/year} \end{aligned}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-STMC-V04-240101

SUNSET DATE: 1/1/2027

⁶⁹⁰ Water use for unknown ENERGY STAR steam cookers is the average of water use values provided by ENERGY STAR for steam generator, boiler-based, and boilerless cookers

3.6.11. Fryer

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR certified fryers installed in a commercial kitchen. ENERGY STAR fryers offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Fry pot insulation reduces standby losses, resulting in lower idle energy rates. Standard-sized ENERGY STAR fryers are up to 30% more efficient, and large-vat ENERGY STAR fryers are up to 35% more efficient, than standard fryers.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR certified fryer meeting idle energy rate (kW or Btu/hr) and cooking efficiency (%) limits, as determined by both fuel type and fryer capacity (standard versus large vat).

ENERGY STAR Requirements (Version 3.0, Effective October 1, 2016)

Fryer Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
Standard Open Deep-Fat Fryer	≤ 800 W	≥ 83%	≤ 9,000 Btu/hr	≥ 50%
Large Vat Open Deep-Fat Fryer	≤ 1,100 W	≥ 80%	≤ 12,000 Btu/hr	

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas fryer that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁹¹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$1,500 for standard electric, \$500 for large vat electric, \$1,000 for standard gas, and \$2,000 for large vat gas fryers.⁶⁹²

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRGCO1 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric fryer below, otherwise use deemed value of 3,128.2 kWh for standard fryers and

⁶⁹¹Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “FSTC research on available models, 2009”

https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

⁶⁹² Measure costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “EPA research on available models using AutoQuotes, October 2020”.

2,537.9 kWh for large vat fryers.⁶⁹³

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = (IdleRate_{Base} * (Hours - FoodCooked/Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked/Production_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

- Hours = Average daily hours of operation
= Custom or if unknown, use 16 hours per day for a standard fryer and 12 hours per day for a large vat fryer
- Days = Annual days of operation
= Custom or if unknown, use 365.25 days per year
- 1,000 = Wh to kWh conversion factor
- FoodCooked = Food cooked per day
= Custom or if unknown, use 150 pounds
- Production_{Base} = Production capacity of baseline electric fryer
= 65 lb/hr for standard fryers and 100 lb/hr for large vat fryers
- Production_{ESTAR} = Production capacity of ENERGY STAR electric fryer
= Custom or if unknown, use 70 lb/hr for standard fryers and 110 lb/hr for large vat fryers
- IdleRate_{Base} = Idle energy rate of baseline electric fryer
= 1,200 W for standard fryers and 1,350 W for large vat fryers
- IdleRate_{ESTAR} = Idle energy rate of ENERGY STAR electric fryer
= Custom or if unknown, use 800 W for standard fryers and 1,100 for large vat fryers
- E_{FOOD} = ASTM energy to food
= 167 Wh/lb
- Eff_{Base} = Cooking efficiency of baseline electric fryer
= 75% for standard fryers and 70% for large vat fryers
- Eff_{ESTAR} = Cooking efficiency of ENERGY STAR electric fryer
= Custom or if unknown, use 83% for standard fryers and 80% for large vat fryers

⁶⁹³ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= (1200 * (16 - 150 / 65)) - (800 * (16 - 150 / 70)) \\ &= 5,345 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (150 * 167 / 0.75) - (150 * 167 / 0.83) \\ &= 3,219 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (5,345 + 3,219) * 365.25 / 1,000 \\ &= 3,128.2 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
= 78.7%

Other variables as defined above.

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

$$\begin{aligned} \Delta kW &= 3,128.2 / (16 * 365.25) * 0.787 \\ &= 0.4213 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas fryer below, otherwise use deemed value of 507.9 therms/yr for standard fryers and 415.1 therms/yr for large vat fryers.⁶⁹⁴

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$\Delta IdleEnergy$ = $(IdleRate_{Base} * (Hours - FoodCooked / Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked / Production_{ESTAR}))$

$\Delta CookingEnergy$ = $(FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$

Where:

100,000 = Btu to therms conversion factor

$Production_{Base}$ = Production capacity of baseline gas fryer
= 60 lb/hr for standard fryers and 100 lb/hr for large vat fryers

$Production_{ESTAR}$ = Production capacity of ENERGY STAR gas fryer

⁶⁹⁴ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

- = Custom or if unknown, use 65 lb/hr for standard fryers and 110 lb/hr for large vat fryers
- IdleRate_{Base} = Idle energy rate of baseline gas fryer
= 14,000 Btu/hr for standard fryers and 16,000 Btu/hr for large vat fryers
- IdleRate_{ESTAR} = Idle energy rate of ENERGY STAR gas fryer
= Custom or if unknown, use 9,000 Btu/hr for standard fryers and 12,000 Btu/hr for large vat fryers
- E_{FOOD} = ASTM energy to food
= 570 Btu/lb
- Eff_{Base} = Cooking efficiency of baseline gas fryer
= 35% for both standard and large vat fryers
- Eff_{ESTAR} = Cooking efficiency of ENERGY STAR gas fryer
= Custom or if unknown, use 50% for both standard and large vat fryers

Other variables as defined above.

For example, an ENERGY STAR standard-sized gas fryer, using default values from above, would save:

$$\Delta\text{Therms} = (\Delta\text{IdleEnergy} + \Delta\text{CookingEnergy}) * \text{Days} / 100,000$$

Where:

$$\begin{aligned} \Delta\text{IdleEnergy} &= (14,000 * (16 - 150 / 60)) - (9,000 * (16 - 150 / 65)) \\ &= 65,769 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (150 * 570 / 0.35) - (150 * 570 / 0.50) \\ &= 73,286 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= (65,769 + 73,286) * 365 / 100,000 \\ &= 507.9 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

$$\Delta\text{Therms} = \text{Natural gas energy savings, calculated above}$$

Other variables as defined above.

For example, an ENERGY STAR standard-sized gas fryer, using default values from above, would save:

$$\begin{aligned} \Delta\text{PeakTherms} &= 507.9 / 365.25 \\ &= 1.3906 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-ESFR-V04-240101

SUNSET DATE: 1/1/2028

3.6.12. Griddle

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR certified griddles installed in a commercial kitchen. ENERGY STAR commercial griddles achieve approximately 10% higher efficiency than standard griddles with strategies such as highly conductive or reflective plate materials and improved thermostatic controls.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new ENERGY STAR electric or natural gas fired griddle meeting idle energy rate limits as determined by fuel type.

ENERGY STAR Requirements (Version 1.2, Effective May 8, 2009 for natural gas and January 1, 2011 for electric griddles)

Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
$\leq 320 \text{ W/ft}^2$ $\leq 1.00 \text{ kW}$	Reported	$\leq 2,650 \text{ Btu/hr/ft}^2$ N/A	Reported

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas fired griddle that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁶⁹⁵

DEEMED MEASURE COST

The incremental capital cost for this measure is \$850 for an electric griddle and \$1,250 for a gas griddle.⁶⁹⁶

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRG01 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric griddle below, otherwise use deemed value of 2,641 kWh for single-sided electric

⁶⁹⁵ Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021, which cites reference as “FSTC research on available models, 2009”

https://www.energystar.gov/sites/default/files/asset/document/CFS_calculator_07-15-2021.xlsx

⁶⁹⁶ Measure cost from Commercial Kitchen Equipment Savings Calculator, which cites reference as “EPA research on available models using AutoQuotes, July 2016”

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

griddle and 3,1813 kWh for double-sided electric griddle.⁶⁹⁷

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy + \Delta PreHeatEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [(IdleRate_{Base} * Width * Length) * (Hours - FoodCooked/Production_{Base})] - [(IdleRate_{ESTAR} * Width * Length) * (Hours - FoodCooked/Production_{ESTAR})]$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

$$\Delta PreHeatEnergy = PreheatEnergy_{Base} - PreHeatEnergy_{ESTAR}$$

Where:

- Hours = Average daily hours of operation
= Custom or if unknown, use 12 hours per day
- Days = Annual days of operation
= Custom or if unknown, use 365.25 days per year
- 1,000 = Wh to kWh conversion factor
- Width = Griddle width
= Custom or if unknown, use 3 feet
- Depth = Griddle depth
= Custom or if unknown, use 2 feet
- FoodCooked = Food cooked per day
= Custom or if unknown, use 100 pounds
- Production_{Base} = Production capacity of baseline electric griddle
= 35 lb/hr for single-sided electric griddle
= 70 lb/hr for double-sided electric griddle
- Production_{ESTAR} = Production capacity of ENERGY STAR electric griddle
= Custom or if unknown, use:
= 40 lb/hr for single-sided electric griddle or,
= 83.5 lb/hr for double-sided electric griddle
- IdleRate_{Base} = Idle energy rate of baseline electric griddle
= 400 W/ft²
- IdleRate_{ESTAR} = Idle energy rate of ENERGY STAR electric griddle
= Custom or if unknown, use 320 W/ft²
- E_{FOOD} = ASTM energy to food
= 139 Wh/lb
- Eff_{Base} = Cooking efficiency of baseline electric griddle
= 65%

⁶⁹⁷ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

Eff_{ESTAR} = Cooking efficiency of ENERGY STAR electric griddle
 = Custom or if unknown, use;
 = 70% for single-sided electric griddle or,
 = 72% for double-sided electric griddle

PreHeatEnergy_{BASE} = Wh used for 1, 15 minute preheat per day of baseline electric griddle
 = 4,000 Wh

PreHeatEnergy_{ESTAR} = Wh used for 1, 15 minute preheat per day of ENERGY STAR electric griddle
 = Custom or if unknown, use:
 = 2,000 Wh

For example, an ENERGY STAR single-sided electric griddle with defaults from the calculation above would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy + \Delta PreHeatEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [400 * (3 * 2) * (12 - 100 / 35)] - [320 * (3 * 2) * (12 - 100 / 40)] = 3,702.9 \text{ Wh}$$

$$\Delta CookingEnergy = (100 * 139 / 0.65) - (100 * 139 / 0.70) = 1,527.5 \text{ Wh} \quad \Delta PreHeatEnergy = (4,000 - 2,000) = 2,000 \text{ Wh}$$

$$\Delta kWh = (3,702.9 + 1,527.5 + 2,000) * 365.25 / 1,000 = 2,640.9 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
 = 78.7%

Other variables as defined above.

For example, a single-sided ENERGY STAR electric griddle with defaults from the calculation above would save:

$$\Delta kW = 2,640.9 / (12 * 365.25) * 0.787 = 0.4741 \text{ kW}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas griddle below, otherwise use deemed value of 153.3 therms for single-sided gas griddles and 221.6 therms for double-sided gas griddles.⁶⁹⁸

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy + \Delta PreHeatEnergy) * Days / 100,000$$

Where:

$$\Delta IdleEnergy = [IdleRate_{BASE} * (Width * Length) * (Hours - FoodCooked / Production_{BASE})] - [IdleRate_{ESTAR}]$$

⁶⁹⁸ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator updated July 15th, 2021

$$* (\text{Width} * \text{Length}) * (\text{Hours} - \text{FoodCooked}/\text{Production}_{\text{ESTAR}}))$$

$$\Delta\text{CookingEnergy} = (\text{FoodCooked} * \text{EFOOD}/\text{Eff}_{\text{Base}}) - (\text{FoodCooked} * \text{EFOOD}/\text{Eff}_{\text{ESTAR}})$$

$$\Delta\text{PreHeatEnergy} = (\text{PreHeatEnergy}_{\text{BASE}} - \text{PreHeatEnergy}_{\text{ESTAR}})$$

Where:

100,000 = Btu to therms conversion factor

$\text{Production}_{\text{Base}}$ = Production capacity of baseline gas griddle
 = 25 lb/hr for single-sided gas griddle
 = 50 lb/hr for double-sided gas griddle

$\text{Production}_{\text{ESTAR}}$ = Production capacity of ENERGY STAR gas griddle
 = Custom or if unknown, use;
 = 45 lb/hr for single-sided gas griddle
 = 69.9 lb/hr for double-sided gas griddle

$\text{IdleRate}_{\text{Base}}$ = Idle energy rate of baseline gas griddle
 = 3,500 Btu/hr/ft²

$\text{IdleRate}_{\text{ESTAR}}$ = Idle energy rate of ENERGY STAR gas griddle
 = Custom or if unknown, use 2,650 Btu/hr/ft²

EFOOD = ASTM energy to food
 = 475 Btu/lb

Eff_{Base} = Cooking efficiency of baseline gas griddle
 = 32%

$\text{Eff}_{\text{ESTAR}}$ = Cooking efficiency of ENERGY STAR gas griddle
 = Custom or if unknown, use;
 = 38% for single-sided gas griddle
 = 35% for double-sided gas griddle

$\text{PreHeatEnergy}_{\text{BASE}}$ = Btu used for 1, 15 min preheat per day of baseline gas griddle
 = 21,000 Btu

$\text{PreHeatEnergy}_{\text{ESTAR}}$ = Btu used for 1, 15 min preheat per day of ENERGY STAR gas griddle
 = Custom or if unknown, use:
 = 15,000 Btu

Other variables as defined above.

For example, a single-sided ENERGY STAR gas griddle with defaults from the calculation above would save:

$$\Delta\text{Therms} = (\Delta\text{IdleEnergy} + \Delta\text{CookingEnergy} + \Delta\text{PreHeatEnergy}) * \text{Days} / 100,000$$

Where:

$$\begin{aligned} \Delta\text{IdleEnergy} &= [3,500 * (3 * 2) * (12 - 100 / 25)] - [2,650 * (3 * 2) * (12 - 100 / 45)] \\ &= 12,533.3 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (100 * 475 / 0.32) - (100 * 475 / 0.38) \\ &= 23,437.5 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{PreHeatEnergy} &= (21,000 - 15,000) \\ &= 6,000 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= (12,533.3 + 23,437.5 + 6,000) * 365.25 / 100,000 \\ &= 221.6 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

$$\Delta\text{Therms} = \text{Natural gas energy savings, calculated above}$$

Other variables as defined above.

For example, a single-sided ENERGY STAR gas griddle with defaults from the calculation above would save:

$$\begin{aligned} \Delta\text{PeakTherms} &= 221.6 / 365.25 \\ &= 0.6067 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-ESGR-V03-240101

SUNSET DATE: 1/1/2028

3.7. Shell Measures

Many of the Nonresidential Shell measures use load hours (LH) to calculate heating and cooling savings. The table with these values is included in this section and referenced in each measure. The benefit of improved shell performance is realized during any period of time air conditioning equipment (both heating and cooling) is in operation, and therefore it follows that system loading hours (as opposed to *effective* full load hours) may more appropriately quantify measure impacts that relate to a building’s shell.

Calculation of LH uses the same approach and base files as EFLH, as described in Section 3.3. To calculate the LH by building type and climate zone provided below, VEIC created OpenStudio and/or eQuest models for each building type. The LH calculation is based on hourly building loads (total heating/cooling output). The calculation allows for a more generally applicable LH determination that is tied to the load profiles of various building prototypes and not affected by modeling irregularities that can be equipment specific. The load profiles are related to system characteristics such as constant vs. variable air volume and single- vs. multi-zone configurations, but not sensitive to how the energy model treats equipment operation at very low loads or performs sizing estimates. The calculation sums the annual total (heating or cooling) load hours.

The models, prototype building descriptions, methodology documentation, and final results can be found on the Iowa TRM SharePoint Site (TRM Reference Documents; Non Residential; Modeling).

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized. For the specific assumptions used in each model, refer to table in the “[IA Prototype Building Descriptions](#)” file in the SharePoint folder referenced above.

Building Type	Zone 5 (Burlington)		Zone 6 (Mason City)		Average/unknown		Weighting Factors for Nonresidential Average ⁶⁹⁹	Model Source
	Heating LH	Cooling LH	Heating LH	Cooling LH	Heating LH	Cooling LH		
Convenience	3024	3005	2129	4054	2690	3628	0%	eQuest
Education	6213	3354	6633	2771	6430	2996	9%	OpenStudio
Grocery	6217	2871	6819	2425	6499	2725	0%	OpenStudio
Health	8729	5240	8732	4405	8720	4770	0%	OpenStudio
Hospital	8286	8760	8272	8760	8289	8760	0%	OpenStudio
Industrial	3396	3537	2233	4526	3080	3977	0%	eQuest
Lodging	5218	8019	6234	7309	5500	7909	0%	OpenStudio
Multifamily	5145	5424	5998	4575	5382	5084	0%	OpenStudio
Office - Large	5037	4844	5787	4457	5316	4596	0%	OpenStudio
Office - Small	4641	3941	5329	3265	5087	3678	26%	OpenStudio
Religious	2485	4347	1667	5267	2223	4763	16%	eQuest
Restaurant	2954	3019	3619	2217	3321	2798	7%	OpenStudio
Retail - Large	2699	3621	1807	4623	2405	4218	5%	eQuest
Retail - Small	4222	2636	4935	1839	4596	2445	11%	OpenStudio
Warehouse	2025	3617	1390	4553	1788	4100	26%	eQuest
Nonresidential Average	3480	3643	3473	3723	3561	3734	N/A	N/A

⁶⁹⁹ The weighting used to average modeled variables into a generic, nonresidential category is based on the number of buildings matching each building type in the 2012 Commercial Buildings Energy Consumption Survey (CBECS) Data for the Midwest Region, West North Central Division, which includes Iowa. Building types that comprise less than 5% of the total population are excluded from the weighted averaging.

3.7.1. 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.⁷⁰⁰ Where this occurs, an algorithm is provided to estimate the site specific savings. Where test in/test out has not occurred, a conservative deemed assumption is provided.

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

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

Note: separate callouts are applicable for Multifamily or mixed use retail plus Multifamily building types. Savings impacts for such building types were modeled using OpenStudio.

DEFINITION OF EFFICIENT EQUIPMENT

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be assessed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

DEFINITION OF BASELINE EQUIPMENT

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly affects the opportunity for cost-effective energy savings through air-sealing.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁷⁰¹

DEEMED MEASURE COST

The actual capital cost for this measure should be used in screening.

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

NREPO1:16 – Nonresidential Electric Heat Pump (by Building Type)

NRGH01:16 – Nonresidential Gas Heating (by Building Type)

E01 – Flat

Algorithm

CALCULATION OF SAVINGS

⁷⁰⁰ Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.

⁷⁰¹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

ELECTRIC ENERGY SAVINGS

Test In / Test Out Approach

For Multifamily, or mixed use retail plus Multifamily building types⁷⁰²:

$$\Delta kWh = \Delta CFM_{50} * (Cool + Fan + Pump + \frac{Heat * 10,000}{(\eta_{heating} * 3,412)})$$

For purposes of loadshape application, components should be separated. Cool savings should use Cooling loadshape. Fan savings should use Flat loadshape for exclusively Multifamily buildings, or an appropriate electric heat loadshape in instances of mixed use. Pump savings should use an appropriate electric heat loadshape. Heat savings should use the appropriate heating loadshape.

Where:

ΔCFM_{50} = Change in infiltration rate between pre and post conditions, as measured by blower door testing at 50 Pascals.

Note: if blower door testing was completed at a pressure of 75 Pa, use the following conversion factor: $CFM_{50} = CFM_{75} / 1.3$

Savings Source Multipliers as noted below, based on climate zone and use type. If building heating is **NOT** electric, Heat = 0 and refer to Natural Gas Savings section:

Climate Zone (City based upon)	Use Type	Cool (kWh/CFM ₅₀)	Fan (kWh/CFM ₅₀)	Pump (kWh/CFM ₅₀)	Heat (therms/CFM ₅₀)
Zone 5 (Burlington)	Multifamily Only	0.03577	0.15331	0.01085	0.11825
Zone 5 (Burlington)	Multifamily / mixed use retail	0.10523	0.17936	0.00967	0.11107
Zone 6 (Mason City)	Multifamily Only	0.03403	0.55017	0.01948	0.21499
Zone 6 (Mason City)	Multifamily / mixed use retail	0.08849	0.31821	0.02013	0.22555
Average/unknown	Multifamily Only	0.03941	0.24876	0.01180	0.14810
Average/unknown	Multifamily / mixed use retail	0.10773	0.24375	0.01225	0.15097

$\eta_{heating}$ = Efficiency of heating system, expressed as COP
 = Actual. For equipment with HSPF ratings, use the following conversion to COP:
 COP = HSPF/3.413

10,000 = Conversion from therms to Btu

3,142 = Conversion from Btu to kWh.

For all other building types:

⁷⁰² Based on OpenStudio modeling results. See measure reference documents for supporting information and assumptions.

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

Where:

$$\Delta kWh_{cooling} = \text{If central cooling, reduction in annual cooling requirement due to air sealing}$$

$$= \frac{(CFM_{Pre} - CFM_{Post}) * 60 * LH_{cooling} * \Delta T_{AVG,cooling} * 0.018 * LM}{(1000 * \eta_{cooling})}$$

CFM_{Pre} = Infiltration at natural conditions as estimated by blower door testing before air sealing
= Actual⁷⁰³

CFM_{Post} = Infiltration at natural conditions as estimated by blower door testing after air sealing
= Actual

60 = Converts Cubic Feet per Minute to Cubic Feet per Hour

LH_{cooling} = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

ΔT_{AVG,cooling} = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	OA _{AVG,cooling} [°F] ⁷⁰⁴	ΔT _{AVG,cooling} [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

0.018 = Specific Heat Capacity of Air (Btu/ft³*°F)

LM = Latent multiplier to account for latent cooling demand
= dependent on location:⁷⁰⁵

Climate Zone (City based upon)	LM
Zone 5 (Burlington)	4.1
Zone 6 (Mason City)	4.2
Average/ unknown	4.2

1000 = Converts Btu to kWh

η_{cooling} = Energy efficiency ratio (EER) of cooling system (kBtu/kWh)

⁷⁰³ 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.

⁷⁰⁴ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

⁷⁰⁵ 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.

= Actual. If not directly specified, EER may be calculated from other commonly listed efficiency ratings (kW/ton or COP):

$$EER = 12 / \text{kW/ton}$$

$$EER = COP \times 3.412$$

$\Delta kWh_{\text{heating}}$ = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \frac{(CFM_{\text{Pre}} - CFM_{\text{Post}}) * 60 * LH_{\text{heating}} * \Delta T_{\text{AVG,heating}} * 0.018}{(\eta_{\text{heating}} * 3,412)}$$

LH_{heating} = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{\text{AVG,heating}}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 55°F heating base temperature

Climate Zone (City based upon)	$OA_{\text{AVG,heating}}$ [°F] ⁷⁰⁶	$\Delta T_{\text{AVG,heating}}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/ unknown	35.9	19.1

3,142 = Conversion from Btu to kWh.

η_{heating} = Efficiency of heating system, expressed as COP

= Actual. For equipment with HSPF ratings, use the following conversion to COP:

$$COP = HSPF/3.413$$

For example, a small retail building (2,000 SqFt) in unknown location with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{\text{cooling}} + \Delta kWh_{\text{heating}} \\ &= [((340 - 225) * 60 * 2,445 * 3.6 * 0.018 * 4.2) / (1000 * 10.5)] + \\ &\quad [((340 - 225) * 60 * 4,596 * 19.1 * 0.018) / (1.92 * 3,412)] \\ &= 437 + 1664 \end{aligned}$$

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment⁷⁰⁷

⁷⁰⁶ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

⁷⁰⁷ The values in the table represent estimates of savings from a 10-15% improvement in air leakage. The values are half those provided by Cadmus for the Joint Assessment, based on building simulations performed. The conservative 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.

End Use	HVAC System	SavingsPerUnit (kWh/ft ²)
Cooling Chillers	Chiller	0.027
Cooling DX	Air Conditioning	0.041
Space Heat	Electric Resistance/Furnace	0.2915
Heat Pump - Cooling	Heat Pump	0.041
Heat Pump - Heating	Heat Pump	0.1885

SqFt = Building square footage
 = Actual

Additional Fan savings

$\Delta kWh_{heating}$ = 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%⁷⁰⁸

29.3 = kWh per therm

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$\Delta kWh = 81 * 0.0314 * 29.3 = 75 \text{ kWh}$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Note: for Multifamily, or mixed use retail plus Multifamily building types,

$$\Delta kWh_{cooling} = \Delta CFM_{50} * Cool$$

Where:

$LH_{cooling}$ = Load hours of air conditioning are provided in Section 3.7, Shell end use. Any building type that contains a portion of multifamily housing should use Multifamily assumptions.

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type). Any building type that contains a portion of multifamily housing should use Multifamily assumptions.

Building Type	CF ⁷⁰⁹	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio

⁷⁰⁸ F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Furnace Fan Analysis.xlsx" for reference.

⁷⁰⁹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ⁷⁰⁹	Model Source
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ⁷¹⁰	92.3%	N/A

For example, a small retail building (2,000 Sq) Ft in unknown location with 10.5 SEER central cooling and a heat pump system with COP of 1.92, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\Delta kW = 437 / 2,445 * 1.00$$

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

For Multifamily, or mixed use retail plus Multifamily building types:

$$\Delta Therms = \Delta CFM_{50} * \frac{Heat}{\eta_{heating}}$$

For all other building types:

$$\Delta Therms = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * LH_{heating} * \Delta T_{AVG,heating} * 0.018}{(\eta_{heating} * 100,000)}$$

Where:

100,000 = Conversion from BTUs to Therms

Other factors as defined above

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned} \Delta Therms &= ((340 - 225) * 60 * 2,954 * 15.4 * 0.018) / (0.70 * 100,000) \\ &= 81 \text{ therms} \end{aligned}$$

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

⁷¹⁰ For weighting factors, see HVAC variable table in section 3.3.

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment⁷¹¹

End Use	HVAC System	SavingsPerUnit (Therms/ft ²)
Space Heat Boiler	Gas Boiler	0.0155
Space Heat Furnace	Gas Furnace	0.0155

SqFt = Building square footage

= Actual

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁷¹²	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁷¹³	1.4658%	N/A

For example, restaurant in Burlington with a gas furnace with system efficiency of 70%, with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned} \Delta PeakTherms &= 81 * 0.015262 \\ &= 1.221 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

⁷¹¹ The values in the table represent estimates of savings from a 10-15% improvement in air leakage. The values are half those provided by Cadmus for the Joint Assessment, based on building simulations performed. The conservative 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.

⁷¹² Calculated as the percentage of total savings in the maximum saving day, from models.

⁷¹³ For weighting factors, see HVAC variable table in section 3.3.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-AIRS-V05-220101

SUNSET DATE: 1/1/2027

3.7.2. Foundation Wall Insulation

DESCRIPTION

Energy and demand savings are realized through reductions in the building cooling and heating loads. Insulation is added to foundation sidewalls. 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. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

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

DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post assembly R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

For retrofit projects, the baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire wall assembly. If existing condition is unknown, assume IECC 2006.

For new construction projects, baseline is building code, IECC 2012.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E’s 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC’s Energy Efficiency Policy Manual v.2, and GDS’s Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

For new construction projects, costs should be limited to incremental material and labor costs associated with the portion of insulation that exceeds code requirements.

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

NREPO1:16 – Nonresidential Electric Heat Pump (by Building Type)

NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}}\right) * Area_{AG} * LH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

$R_{existingAG}$ = Above grade wall heat loss coefficient, with existing insulation, for the complete structural assembly [(hr-°F-ft²)/Btu]⁷¹⁴

R_{newAG} = Above grade wall heat loss coefficient, with new insulation, for the complete structural assembly [(hr-°F-ft²)/Btu]

$Area_{AG}$ = Area of the above grade wall surface in square feet

$LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$\Delta T_{AVG,cooling}$ [°F] ⁷¹⁵	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}}\right) * Area_{AG}\right) + \left(\left(\frac{1}{R_{existingBG}} - \frac{1}{R_{newBG}}\right) * Area_{BG}\right)}{(3,412 * \eta_{heating})} * LH_{heating} * \Delta T_{AVG,heating}$$

Where:

$R_{existingBG}$ = Below grade wall assembly heat loss coefficient with existing insulation, for the complete structural assembly [(hr-°F-ft²)/Btu]

⁷¹⁴ In addition to the nominal value of the insulation, assembly design and materials also need to be considered for their impact on the overall insulation properties of the complete structural assembly. This exercise is best left as a site or project specific determination. For those desiring a more streamlined or prescriptive approach toward estimating assembly R-values, ASHRAE Standard 90.1 2019 dedicates Normative Appendix A “Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations” to outline an approach using convenient lookup tables.

⁷¹⁵ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

= Actual R-value of wall assembly plus “Average Earth R-value” by depth in table below⁷¹⁶
 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

R_{newBG} = Below grade wall assembly heat loss coefficient with new insulation, for the complete structural assembly [(hr-°F-ft²)/Btu]

$Area_{BG}$ = Area of the below grade wall surface in square feet.

$LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 55°F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ⁷¹⁷	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

3,412 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system
 = Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

$\Delta Therms$ = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%⁷¹⁸

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

⁷¹⁶ 6 Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

⁷¹⁷ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3

http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

⁷¹⁸ Fe 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% Fe . See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

$$\Delta kW = (\Delta kWh_{cooling} / LH_{cooling}) * CF$$

Where:

$LH_{cooling}$ = Load hours of air conditioning are provided in Section 3.7, Shell end use

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁷¹⁹	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ⁷²⁰	92.3%	N/A

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

Δ Therms

$$= \frac{\left(\left(\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}} \right) * Area_{AG} \right) + \left(\left(\frac{1}{R_{existingBG}} - \frac{1}{R_{newBG}} \right) * Area_{BG} \right) \right) * LH_{heating} * \Delta T_{AVG,heating}}{(100,000 * \eta_{heat})}$$

Where:

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

Other terms as defined above.

PEAK GAS SAVINGS

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

Where:

Δ Therms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

⁷¹⁹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁷²⁰ For weighting factors, see HVAC variable table in section 3.3.

Building Type	GCF ⁷²¹	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁷²²	1.4658%	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-FINS-V05-240101

SUNSET DATE: 1/1/2028

⁷²¹ Calculated as the percentage of total savings in the maximum saving day, from models.

⁷²² For weighting factors, see HVAC variable table in section 3.3.

3.7.3. Roof Insulation

DESCRIPTION

Energy and demand savings are realized through reductions in the building cooling and heating loads.

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

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. IECC 2012 requirements are shown in the following tables:

	ASHRAE/IECC Climate Zone 5 (A, B, C)	
	Assembly Maximum	Insulation Min. R-Value
Insulation entirely above deck	U-0.039	R-25 ci
Metal building (with R-5 thermal blocks)	U-0.035	R-19 + R-11 LS
Attic and other	All other: U-0.027 Group R: U-0.021	All other: R-38 Group R: R-49

	ASHRAE/IECC Climate Zone 6 (A, B, C)	
	Assembly Maximum	Insulation Min. R-Value
Insulation entirely above deck	U-0.032	R-30 ci
Metal building (with R-5 thermal blocks)	U-0.031	R-25 + R-11 LS
Attic and other	U-0.021	R-49

Note: ci = continuous insulation, LS = Liner System

DEFINITION OF BASELINE EQUIPMENT

The retrofit baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire roof assembly. If existing condition is unknown, assume IECC 2006.

The new construction baseline is code requirement, IECC 2012.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E’s 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC’s Energy Efficiency Policy Manual v.2, and GDS’s Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

For new construction projects, costs should be limited to incremental material and labor costs associated with the portion of insulation that exceeds code requirements.

LOADSHAPE

- NREC01:16 – Nonresidential Cooling (by Building Type)
- NREH01:16 – Nonresidential Electric Heat (by Building Type)
- NREP01:16 – Nonresidential Electric Heat Pump (by Building Type)
- NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building:

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $R_{existing}$ = Complete roof assembly heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]⁷²³
- R_{new} = Complete roof assembly heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- Area = Area of the insulated roof surface in square feet, as measured from within the conditioned space (area of overhangs or eaves should be excluded, for example).
- $LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use
- $\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁷²⁴	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

- 1,000 = Conversion from Btu to kWh
- $\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kWh/kWh)

⁷²³ In addition to the nominal value of the insulation, assembly design and materials also need to be considered for their impact on the overall insulation properties of the complete structural assembly. This exercise is best left as a site or project specific determination. For those desiring a more streamlined or prescriptive approach toward estimating assembly R-values, ASHRAE Standard 90.1 2019 dedicates Normative Appendix A “Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations” to outline an approach using convenient lookup tables.

⁷²⁴ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{\text{heating}} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}}\right) * Area * LH_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(3,412 * \eta_{\text{heating}})}$$

Where:

- LH_{heating} = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use
- $\Delta T_{\text{AVG,heating}}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 55°F heating base temperature

Climate Zone (City based upon)	$OA_{\text{AVG,heating}}$ [°F] ⁷²⁵	$\Delta T_{\text{AVG,heating}}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

- 3,142 = Conversion from Btu to kWh.
- η_{heating} = Efficiency of heating system
= Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft² of R-20 roof insulated to R-35, 10.5 SEER central AC, and 1.92 COP heat pump system:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{\text{cooling}} + \Delta kWh_{\text{heating}} \\ &= ((1/20 - 1/35) * 1,500 * 1.0 * 1,839 * 0.2 / (1,000 * 10.5)) + ((1/20 - 1/35) * 1,500 * 1.0 * 4,935 * 24.9 / (3,412 * 1.92)) \\ &= 1.1 + 602.9 \\ &= 604 \text{ kWh} \end{aligned}$$

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.

$$\Delta kWh_{\text{heating}} = \Delta \text{Therms} * F_e * 29.3$$

Where:

- ΔTherms = Gas savings calculated with equation below.
- F_e = Percentage of heating energy consumed by fans, assume 3.14%⁷²⁶

⁷²⁵ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

⁷²⁶ 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.

29.3 = Conversion from therms to kWh

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft² of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta kWh &= 56.5 * 0.0314 * 29.3 \\ &= 52.0 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

LH_{cooling} = Load hours of air conditioning are provided in Section 3.7, Shell end use

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁷²⁷	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ⁷²⁸	92.3%	N/A

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft² of R-20 roof insulated to R-35, and 10.5 SEER central AC:

$$\begin{aligned} \Delta kW &= 1.1/1,839 * 1.00 \\ &= 0.0006 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

⁷²⁷ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models..

⁷²⁸ For weighting factors, see HVAC variable table in section 3.3.

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta\text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}}\right) * \text{Area} * LH_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

- R_{existing} = Complete roof heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
- R_{new} = Complete roof heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- Area = Area of the insulated roof surface in square feet. Assume 1000 sq ft for planning.
- LH_{heating} = Load Hours for Heating are provided in Section 3.7, Shell end use
- $\Delta T_{\text{AVG,heating}}$ = Average temperature difference [°F] during heating season (see above)
- 100,000 = Conversion from BTUs to Therms
- η_{heat} = Efficiency of heating system
= Actual

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft² of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta\text{Therms} &= ((1/20 - 1/35) * 1,500 * 1.0 * 4,4584,935 * 24.9 / (100,000 * 0.70)) \\ &= 56.5 \text{ therms} \end{aligned}$$

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * GCF$$

Where:

- ΔTherms = Therm impact calculated above
- GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁷²⁹	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest

⁷²⁹ Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF ⁷²⁹	Model Source
Nonresidential Average ⁷³⁰	1.4658%	N/A

For example, for a small retail building with insulation entirely above deck in Climate Zone 6 with 1,500 ft² of R-20 roof insulated to R-35, and a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta\text{PeakTherms} &= 56.5 * 0.014055 \\ &= 0.794 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-XINS-V06-240101

SUNSET DATE: 1/1/2028

⁷³⁰ For weighting factors, see HVAC variable table in section 3.3.

3.7.4. Wall Insulation

DESCRIPTION

Energy and demand saving are realized through reductions in the building cooling and heating loads.

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

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. IECC 2012 requirements are shown in the following tables:

ASHRAE/IECC Climate Zone 5 (A, B, C) Nonresidential		
	Assembly Maximum	Insulation Min. R-Value
Mass	U-0.078	R-11.4 ci
Metal Building	U-0.052	R-13 + R-13 ci
Metal Framed	U-0.064	R-13 + R-7.5 ci
Wood Framed and Other	U-0.064	R-13 + R-3.8 ci or R-20

ASHRAE/IECC Climate Zone 6 (A, B, C) Nonresidential		
	Assembly Maximum	Insulation Min. R-Value
Mass	U-0.078	R-13.1 ci
Metal Building	U-0.052	R-13 + R-13 ci
Metal Framed	U-0.064	R-13 + R-7.5 ci
Wood Framed and Other	U-0.051	R-13 + R-7.5 ci or R-20 + R-3.8 ci

Note: ci = continuous insulation

DEFINITION OF BASELINE EQUIPMENT

The retrofit baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire wall assembly. If existing condition is unknown, assume IECC 2006.

The new construction baseline is code requirement, IECC 2012.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E’s 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC’s Energy Efficiency Policy Manual v.2, and GDS’s Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

For new construction projects, costs should be limited to incremental material and labor costs associated with the portion of insulation that exceeds code requirements.

LOADSHAPE

- NREC01:16 – Nonresidential Cooling (by Building Type)
- NREH01:16 – Nonresidential Electric Heat (by Building Type)
- NREP01:16 – Nonresidential Electric Heat Pump (by Building Type)
- NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building.

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is:

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $R_{existing}$ = Complete wall assembly heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]⁷³¹
- R_{new} = Complete wall assembly heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- Area = Area of the wall surface in square feet.
- $LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use
- $\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁷³²	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

⁷³¹ In addition to the nominal value of the insulation, assembly design and materials also need to be considered for their impact on the overall insulation properties of the complete structural assembly. This exercise is best left as a site or project specific determination. For those desiring a more streamlined or prescriptive approach toward estimating assembly R-values, ASHRAE Standard 90.1 2019 dedicates Normative Appendix A “Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations” to outline an approach using convenient lookup tables.

⁷³² National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

- 1,000 = Conversion from Btu to kBtu
- $\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
- = Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * LH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

Where:

- $LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use
- $\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 55°F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ⁷³³	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

- 3,412 = Conversion from Btu to kWh.
- $\eta_{heating}$ = Efficiency of heating system
- = Actual. *Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%*

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta Therms * F_e * 29.3$$

Where:

- $\Delta Therms$ = Gas savings calculated with equation below.
- F_e = Percentage of heating energy consumed by fans, assume 3.14%⁷³⁴
- 29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

⁷³³ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

⁷³⁴ 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.

LH_{cooling} = Load hours of air conditioning are provided in Section 3.7, Shell end use
 CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁷³⁵	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ⁷³⁶	92.3%	N/A

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta\text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}}\right) * \text{Area} * LH_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

- R_{existing} = Complete wall heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
- R_{new} = Complete wall heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- Area = Area of the wall surface in square feet. Assume 1000 sq ft for planning.
- LH_{heating} = Load Hours for Heating are provided in Section 3.7, Shell end use
- ΔT_{AVG,heating} = Average temperature difference [°F] during heating season (see above)
- 100,000 = Conversion from BTUs to Therms
- η_{heat} = Efficiency of heating system
= Actual

PEAK GAS SAVINGS

$$\Delta\text{PeakTherms} = \Delta\text{Therms} * GCF$$

Where:

⁷³⁵ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.
⁷³⁶ For weighting factors, see HVAC variable table in section 3.3.

ΔTherms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁷³⁷	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁷³⁸	1.4658%	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-WINS-V04-240101

SUNSET DATE: 1/1/2028

⁷³⁷ Calculated as the percentage of total savings in the maximum saving day, from models.

⁷³⁸ For weighting factors, see HVAC variable table in section 3.3.

3.7.5. 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. For a comprehensive estimate of impacts, including the effects of solar gains, computer modeling is recommended.

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 and a Solar Heat Gain Coefficient (SHGC) that is at least equal to but not greater than code requirements (0.4).

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a window assembly with a U-factor and Solar Heat Gain Coefficient (SHGC) that are equal to code requirements, IECC 2012.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.⁷³⁹

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be \$1.50 per square foot of window area.⁷⁴⁰

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

NREP01:16 – Nonresidential Electric Heat Pump (by Building Type)

NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF SAVINGS

The following calculations apply to a single window assembly. Note that the effects of a lower SHGC are not considered in this characterization. A lower SHGC does not necessarily equate to net savings due to the possible opposite effects it can have on heating and cooling loads. For optimum design and estimation of impacts from solar gain, a custom analysis should be performed that takes into account building site and orientation considerations.

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

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

⁷³⁹ Consistent with window measure lives specified in the MidAmerican Energy Company Joint Assessment, February 2013.

⁷⁴⁰ Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007. Consistent with other market reports.

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{(U_{code} - U_{eff}) * A_{window} * LH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

U_{code} = U-factor value of code baseline window assembly (Btu/ft².°F.h)
 = Dependent on climate zone and window type. If unknown, assume the most conservative value, 0.36. See table below for IECC2012 requirements:

		Climate Zone	
		5	6
U-Factor, based on window type	Fixed	0.38	0.36
	Openable	0.45	0.43

U_{eff} = U-factor value of the efficient window assembly (Btu/ft².°F.h)
 = Actual.

A_{window} = Area of insulated window (including visible frame and glass) (ft²)

$LH_{cooling}$ Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁷⁴¹	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

1,000 = Conversion from Btu to kWh

$\eta_{cooling}$ = Energy efficiency ratio (EER) of cooling system (kWh/kWh)
 = Actual. If not directly specified, EER may be calculated from other commonly listed efficiency ratings (kW/ton or COP):
 $EER = 12 / kW/ton$
 $EER = COP * 3.412$
 = if unknown, adopt the default baseline efficiency of the relevant HVAC equipment as defined by the corresponding TRM characterization

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{(U_{code} - U_{eff}) * A_{window} * LH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

Where:

⁷⁴¹ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

LH_{heating} = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use

$\Delta T_{\text{AVG,heating}}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 55°F heating base temperature

Climate Zone (City based upon)	$OA_{\text{AVG,heating}}$ [°F] ⁷⁴²	$\Delta T_{\text{AVG,heating}}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

3,142 = Conversion from Btu to kWh.

η_{heating} = Efficiency of heating system, expressed as COP

= Actual. For equipment with HSPF ratings, use the following conversion to COP:
 $COP = HSPF/3.413$

= if unknown, adopt the default baseline efficiency of the relevant HVAC equipment as defined by the corresponding TRM characterization

For example, for a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2' x 4' operable windows with a 0.25 U-Factor, savings with a 12.0 EER AC system and a 1.92 COP Heat Pump system:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{\text{cooling}} + \Delta kWh_{\text{heating}} \\ &= (((0.43 - 0.25) * 8 * 2,217 * 0.2) / (1000 * 12.0)) + (((0.43 - 0.25) * 8 * 3,619 * 24.9) / (3,412 * 1.92)) * 15 \\ &= (0.053 + 19.8) * 15 \\ &= 397.8 \text{ kWh} \end{aligned}$$

Other factors as defined above.

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{\text{heating}} = \Delta \text{Therms} * F_e * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

F_e = Percentage of heating energy consumed by fans, assume 3.14%⁷⁴³

29.3 = Conversion from therms to kWh

⁷⁴² National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

⁷⁴³ 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.

For example, for a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2' x 4' operable windows with a 0.25 U-Factor, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta kWh &= 73.0 * 0.0314 * 29.3 \\ &= 67.2 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- LH_{cooling} = Load hours of air conditioning are provided in Section 3.7, Shell end use
- CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁷⁴⁴	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ⁷⁴⁵	92.3%	N/A

For example, for a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2' x 4' operable windows with a 0.25 U-Factor, savings with a 12.0 EER AC system:

$$\begin{aligned} \Delta kW &= (0.053 * 15) / 2,217 * 0.996 \\ &= 0.0004 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{(U_{code} - U_{eff}) * A_{window} * LH_{heating} * \Delta T_{AVG,heating}}{(100,000 * \eta_{heat})}$$

Where:

- U_{code} = U-factor value of code baseline window assembly (Btu/ft².°F.h)

⁷⁴⁴ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from models.

⁷⁴⁵ For weighting factors, see HVAC variable table in section 3.3.

= Dependent on climate zone and window type. See table below:

		Climate Zone	
		5	6
U-Factor, based on window type	Fixed	0.38	0.36
	Openable	0.45	0.43

U_{eff} = U-factor value of the efficient window assembly (Btu/ft².°F.h)

= Actual.

A_{window} = Net area of insulated window (ft²)

$LH_{heating}$ = Load Hours for Heating are provided in Section 3.7, Shell end use

$\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

= if unknown, adopt the default baseline efficiency of the relevant HVAC equipment as defined by the corresponding TRM characterization

For example, a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2' x 4' openable windows with a 0.25 U-Factor, savings with a gas furnace with system efficiency of 70%:

$$\Delta Therms = (((0.43 - 0.25) * 21 * 3,6194,767 * 24.9) / (100,000 * 0.70)) * 15$$

$$= 73.0$$

PEAK GAS SAVINGS

$$\Delta Peak Therms = \Delta Therms * GCF$$

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁷⁴⁶	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio

⁷⁴⁶ Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF ⁷⁴⁶	Model Source
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁷⁴⁷	1.4658%	N/A

For example, a restaurant in Mason City (climate zone 6) installing 15 new identically sized 2’ x 4’ operable windows with a 0.25 U-Factor, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta\text{PeakTherms} &= 73.0 * 0.015262 \\ &= 1.11 \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-WIND-V05-210101

SUNSET DATE: 1/1/2024*

* 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.

⁷⁴⁷ For weighting factors, see HVAC variable table in section 3.3.

3.7.6. Insulated Doors

DESCRIPTION

Energy and demand savings are realized through reductions in the building cooling and heating loads.

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 an **exterior door** with 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 of the **exterior door** and requires assessment of the existing insulation. It should be based on the entire door assembly. If existing condition is unknown, assume IECC 2006.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 25 years.⁷⁴⁸

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

LOADSHAPE

NREC01:16 – Nonresidential Cooling (by Building Type)

NREH01:16 – Nonresidential Electric Heat (by Building Type)

NREP01:16 – Nonresidential Electric Heat Pump (by Building Type)

NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * LH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

⁷⁴⁸ FannieMae Estimated useful life tables for multifamily properties, judged to be applicable to C&I facilities as well.

- $R_{existing}$ = Existing door heat loss coefficient [(hr-°F-ft²)/Btu]. If unknown, assume 1.43 for swinging doors, 0.69 for roll-up or sliding doors in zone 5, and 2.0 for roll-up or sliding doors in zone 6.⁷⁴⁹
- R_{new} = New door heat loss coefficient [(hr-°F-ft²)/Btu]
- Area = Area of the door surface in square feet.
- $LH_{cooling}$ = Load Hours for Cooling [hr] are provided in Section 3.7, Shell end use
- $\Delta T_{AVG,cooling}$ = Average temperature difference [°F] during cooling season between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁷⁵⁰	$\Delta T_{AVG,cooling}$ [°F]
Zone 5 (Burlington)	80.4	5.4
Zone 6 (Mason City)	75.2	0.2
Average/unknown	78.6	3.6

- 1,000 = Conversion from Btu to kBtu
- $\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * LH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

Where:

- $LH_{heating}$ = Load Hours for Heating [hr] are provided in Section 3.7, Shell end use
- $\Delta T_{AVG,heating}$ = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 55°F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ⁷⁵¹	$\Delta T_{AVG,heating}$ [°F]
Zone 5 (Burlington)	39.6	15.4
Zone 6 (Mason City)	30.1	24.9
Average/unknown	35.9	19.1

- 3,412 = Conversion from Btu to kWh.
- $\eta_{heating}$ = Efficiency of heating system

⁷⁴⁹ IECC 2006 code requirement

⁷⁵⁰ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3
http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

⁷⁵¹ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3
http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

= Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{\text{heating}} = \Delta \text{Therms} * F_e * 29.3$$

Where:

- ΔTherms = Gas savings calculated with equation below.
- F_e = Percentage of heating energy consumed by fans, assume 3.14%⁷⁵²
- 29.3 = Conversion from therms to kWh

For example, for a restaurant in Mason City installing a new 21 ft², insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta kWh &= 16.45 * 0.0314 * 29.3 \\ &= 15.13 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh_{\text{cooling}} / LH_{\text{cooling}}) * CF$$

Where:

- LH_{cooling} = Load hours of air conditioning are provided in Section 3.7, Shell end use
- CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁷⁵³	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest

⁷⁵² F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e . See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

⁷⁵³ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ⁷⁵³	Model Source
Nonresidential Average ⁷⁵⁴	92.3%	N/A

For example, for a restaurant in Mason City installing a new 21 ft², insulated, swinging door with an R-value of 11, savings with a 10.5 SEER central AC system:

$$\begin{aligned} \Delta kW &= 0.5 / 2,217 * 0.996 \\ &= 0.00022 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}} \right) * \text{Area} * LH_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

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.
- LH_{heating} = Load Hours for Heating are provided in Section 3.7, Shell end use
- ΔT_{AVG,heating} = Average temperature difference [°F] during heating season (see above)
- 100,000 = Conversion from BTUs to Therms
- η_{heat} = Efficiency of heating system
- = Actual

For example, for a restaurant in Mason City installing a new 21 ft², insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta \text{Therms} &= (((1/1.43 - 1/11) * 21 * 3,619 * 24.9) / (100,000 * 0.70)) \\ &= 16.45 \end{aligned}$$

PEAK GAS SAVINGS

$$\Delta \text{PeakTherms} = \Delta \text{Therms} * GCF$$

Where:

- ΔTherms = Therm impact calculated above
- GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁷⁵⁵	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio

⁷⁵⁴ For weighting factors, see HVAC variable table in section 3.3.

⁷⁵⁵ Calculated as the percentage of total savings in the maximum saving day, from models.

Building Type	GCF ⁷⁵⁵	Model Source
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁷⁵⁶	1.4658%	N/A

For example, for a restaurant in Mason City installing a new 21 ft², insulated, swinging door with an R-value of 11, savings with a gas furnace with system efficiency of 70%:

$$\begin{aligned} \Delta\text{PeakTherms} &= 16.45 * 0.0152620 \\ &= 0.251 \text{ therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-DOOR-V06-240101

SUNSET DATE: 1/1/2027

⁷⁵⁶ For weighting factors, see HVAC variable table in section 3.3.

3.8. Refrigeration

3.8.1. LED Refrigerator Case Light Occupancy Sensor

DESCRIPTION

Occupancy sensors are devices that reduce lighting levels and/or turn lights on or off in response to the presence (or absence) of people in a defined area. This measure applies to the installation of occupancy sensors on linear LED lights on commercial glass-door, reach-in coolers and freezers. Savings result from a reduction in electric energy use by case lighting and from a reduced cooling load due to less heat gain from the lighting.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be occupancy sensors meeting program requirements, installed on linear LED lights on commercial glass-door, reach-in coolers and freezers.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is linear LED lights without occupancy controls, installed on commercial glass-door, reach-in coolers and freezers.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 8 years.⁷⁵⁷

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, use a default value of \$60 per control.⁷⁵⁸

LOADSHAPE

Loadshape NREL01 – Nonresidential Lighting – Convenience

Loadshape NREL03 – Nonresidential Lighting – Grocery

Loadshape NREL13 – Nonresidential Lighting – Retail – Large

Loadshape NREL14 – Nonresidential Lighting – Retail – Small

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use 290.8 kWh per control for coolers and 331.4 kWh per control for freezers.

$$\Delta kWh = kW_{Controlled} * (Hours * \%Controlled) * (1 + (0.80/COP))$$

⁷⁵⁷2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

⁷⁵⁸ Measure cost from Efficiency Vermont No. 2015-90 TRM. Based on information provided by Green Mountain Electric Supply for a Wattstopper FS705 product.

Where:

- $kW_{Controlled}$ = Total lighting load (kW) connected to the control.
= Actual, or if unknown, assume 0.090 kW⁷⁵⁹
- Hours = Annual case lighting hours of use
= Actual or if unknown, assume 6,575 hours⁷⁶⁰
- %Controlled = Percentage savings due to the occupancy sensor
= Actual or if unknown, assume 40%⁷⁶¹
- 0.80 = Percentage of heat from LED lighting assumed to be transferred to the refrigeration system
- COP = Coefficient of performance of cooler or freezer
= Actual or if unknown, use 3.5 for coolers, 2.0 for freezers, or 2.5 for unknown cooler type⁷⁶²

For example, a cooler with an LED case light occupancy sensor installed, using the defaults above, would save:

$$\begin{aligned} \Delta kWh &= kW_{Controlled} * (Hours * \%Controlled) * (1 + (0.80 / COP)) \\ \Delta kWh &= 0.090 * (6,575 * 0.40) * (1 + (0.80 / 3.5)) \\ &= 290.8 kWh \text{ per control} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- CF = Summer peak coincidence factor
= 100% for all building types

Other variables as defined above

For example, a cooler with an LED case light occupancy sensor installed, using the defaults above, would save:

$$\begin{aligned} \Delta kW &= (290.8 / 6,575) * 1.00 \\ &= 0.044 kW \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

⁷⁵⁹ Controlled lighting load from Efficiency Vermont No. 2018 TRM, based on LED Refrig Lighting ERCO_Talking_PointsV3, PG&E

⁷⁶⁰ Assumption for a business operating 18 hours per day

⁷⁶¹ Case occupancy sensors are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls.

⁷⁶² COP values from Efficiency Vermont No. 2015-90 TRM, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F (freezers) and 20°F (coolers), and a condensing temperature of 90°F. Unknown cooler type COP value is sourced from Oak Ridge National Laboratory, "Permanent Magnet Synchronous Motors for Commercial Refrigeration: Final Report", 2019, Section 4.3.2.2

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-CLOS-V02-240101

SUNSET DATE: 1/1/2028

3.8.2. Door Heater Controls for Cooler or Freezer

DESCRIPTION

This measure applies to door heater controls installed on commercial coolers or freezers. There are two main categories of commercially available control strategies that achieve “on-off” control of door heaters based on either (1) the relative humidity of the air in the store or (2) the “conductivity” of the door (which drops when condensation appears). In the first strategy, the system activates door heaters when the relative humidity in a store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint. Savings result from a reduction in electric energy use due to heaters not running continuously and from reduced cooling loads when heaters are off. The assumptions included within this measure assume that door heater controls which are properly designed and commissioned will achieve approximately equivalent savings, regardless of control strategy.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a door heater control installed on a commercial glass door cooler or freezer.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a door heater without controls, installed on a commercial glass door cooler or freezer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁷⁶³

DEEMED MEASURE COST

Actual equipment and labor costs should be used if available. In actual costs are unknown, assume a full installed cost of \$1,266 per heater control.⁷⁶⁴

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Doors * \left(kW_{Base} * Hours * \%Off * \left(1 + \frac{R_H}{COP} \right) \right)$$

Where:

kW_{Base} = Per door electric energy consumption of door heater

⁷⁶³ Commercial Refrigeration Anti-Sweat Heater Controls, California Technical Forum, Workpaper SWCR001-01, May 2019

⁷⁶⁴ Measure cost from “Incremental Cost Study, Phase Four Final Report.” Northeast Energy Efficiency Partnerships. June 15, 2015.

	= Assume 0.066 kW for coolers and 0.230 kW for freezers ⁷⁶⁵
Doors	= Number of doors controlled by sensor = Actual
Hours	= Annual hours of cooler or freezer operation = Assume 8,760 hours per year
%Off	= Percentage of hours annually that the door heater element is powered off due to controls = 45.1% for coolers and freezers ⁷⁶⁶
R _H	= Residual heat fraction: estimated percentage of heat produced by heaters that remains in the freezer or cooler case and must be removed by the refrigeration unit = Actual or if unknown, use 0.65 ⁷⁶⁷
COP	= Coefficient of performance of cooler or freezer = Actual or if unknown, use 3.5 for coolers, 2.0 for freezers, or 2.5 for unknown cooler type ⁷⁶⁸

For example, a 3-door reach-in cooler with a door heater control would save:

$$\begin{aligned} \Delta kWh &= \text{Doors} * (\text{kW}_{\text{Base}} * \text{Hours} * \text{ESF} * (1 + R_H / \text{COP})) \\ \Delta kWh &= 3 * (0.066 * 8,760 * 0.451 * (1 + 0.65 / 3.5)) \\ &928 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh	= Electric energy savings, calculated above
CF	= Summer peak coincidence factor = 96.4%

Other variables as defined above.

⁷⁶⁵ Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁷⁶⁶ Difference in effective runtime of an uncontrolled heater and all control style heater controls. Anti-sweat door heater control reduced run time. The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 69, Section 4.1.4, Table 37.

⁷⁶⁷ Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁷⁶⁸ COP values from Efficiency Vermont October 22, 2015 TRM, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F (freezers) and 20°F (coolers), and a condensing temperature of 90°F. Unknown cooler type COP value is sourced from Oak Ridge National Laboratory, "Permanent Magnet Synchronous Motors for Commercial Refrigeration: Final Report", 2019, Section 4.3.2.2

For example, a 3-door reach-in cooler with a door heater control would save:

$$\begin{aligned}\Delta kW &= (928/8760) * 0.964 \\ &= 0.1021 \text{ kW}\end{aligned}$$

NATURAL GAS ENERGY 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: NR-RFG-DHCT-V04-240101

SUNSET DATE: 1/1/2026

3.8.3. Efficient Motors for Walk-in and Display Case Coolers / Freezers

DESCRIPTION

This measure applies to the replacement of an existing permanent split capacitor (PSC) evaporator fan motor with an electrically commutated motor (ECM) or Q-Sync motor on commercial walk-in or display case coolers or freezers. Savings result from a reduction in electric energy use from a more efficient fan motor and from a reduced cooling load due to less heat gain from a more efficient fan motor in the air stream.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ECM or Q-Sync installed on a commercial walk-in or display case cooler or freezer.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard-efficiency PSC fan motor installed on a commercial walk-in or display case cooler or freezer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁷⁶⁹

DEEMED MEASURE COST

Actual equipment and labor costs should be used if available. In actual costs are unknown, the full installed cost for a brushless DC fan or Q-Sync type motor is \$305 (\$231 for the motor, \$74 for installation labor including travel time).⁷⁷⁰

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use default savings values in table below.

$$\Delta kWh = \frac{W_{Output} / EFF_{Base} - W_{Output} / EFF_{EE}}{1,000} \times Hours \times DC \times LF \times \left(1 + \frac{1}{COP}\right)$$

Where:

W_{Output} = Output wattage of installed fan motor

⁷⁶⁹ DEER 2014 Work Paper PGE3PREF126, as referenced in 2023 IL TRM version 11, Measure 4.6.4

⁷⁷⁰ Full incremental cost of motor and labor sourced from DEER 2014 Work Paper PGE3PREF126 (cost of the controller (\$70) and controller install labor (\$92) excluded). Q-Sync and ECM motors combined into single category based on AESC, "ENERGY SAVINGS OF PERMANENT MAGNET SYNCHRONOUS FAN MOTOR ASSEMBLY REFRIGERATED CASE EVAPORATORS", May 2016, pg 26: "new PMSM fan (sync) is estimated to have same cost as a similar ECM model".

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.3 Efficient Motors for Walk-in and Display Case Coolers / Freezers

- = Actual; or if unknown, use 14.95 W for display cases⁷⁷¹ or 42 W for walk-ins⁷⁷²
- EFF_{Base} = Efficiency of baseline motor
= Actual or if unknown, use 29%⁷⁷³
- EFF_{EE} = Efficiency of efficient motor
= Actual or if unknown, use 66% for ECM or 75% for Q-Sync⁷⁵²
- 1,000 = Conversion factor from watts to kilowatts
- Hours = Annual hours of cooler or freezer operation
= Assume 8,760 hours
- LF = Load factor of fan motor
= Actual or if unknown, assume 0.90⁷⁷⁴
- DC = Duty cycle of fan motor
= Custom or if unknown, assume 100%⁷⁷⁵
- COP = Coefficient of performance of cooler or freezer
= Actual or if unknown, use 3.5 for coolers, 2.0 for freezers, or 2.5 for unknown cooler type⁷⁷⁶

For example, a display cooler with an ECM motor installed in place of a PSC motor, using the defaults above, would save:

$$\Delta \text{kWh} = (W_{\text{Output}} / \text{EFF}_{\text{Base}} - W_{\text{Output}} / \text{EFF}_{\text{EE}}) / 1,000 \times \text{Hours} \times \text{DC} \times \text{LF} \times (1 + 1/\text{COP})$$

$$\Delta \text{kWh} = (14.95/0.29 - 14.95/0.66) / 1,000 * 8760 * 1.00 * 0.90 * (1 + 1/2.5)$$

$$= 319.0 \text{ kWh}$$

Savings for all efficient motor types are presented in the table below:

Refrigeration Type	Application	Installed Motor Type	Savings (kWh)
Cooler	Display Case	ECM	319.0
		Q-Sync	349.0
	Walk-in	ECM	896.2

⁷⁷¹ Weighted average of output motor wattages from invoices submitted to EnergySmart Grocer program. RTF Unit Energy Savings (UES) Measures and Supporting Documentation: Grocery - ECMs for Display Cases v.3.1

⁷⁷² The Cadmus Group, *Commercial Refrigeration Loadshape Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, October 2015. Walk-in motor wattage derived using motor type efficiencies and output ratings. Calculated power consumption comparable to NEEP loadshape reported values for walk-in motors.

⁷⁷³ Chapter 5 of Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Commercial Refrigeration Equipment, Table 5.5.12, June 2022

⁷⁷⁴ Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁷⁷⁵ Duty cycle from 2023 IL TRM Version 11 Measure 4.6.4: “operating 8760 hours continuously in a refrigerated display case or fan coil unit of a walk-in cooling unit”

⁷⁷⁶ COP values from Efficiency Vermont October 22, 2015 TRM, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F (freezers) and 20°F (coolers), and a condensing temperature of 90°F. Unknown cooler type COP value is sourced from Oak Ridge National Laboratory, “Permanent Magnet Synchronous Motors for Commercial Refrigeration: Final Report”, 2019, Section 4.3.2.2

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.3 Efficient Motors for Walk-in and Display Case Coolers / Freezers

Refrigeration Type	Application	Installed Motor Type	Savings (kWh)
		Q-Sync	980.4
Freezer	Display Case	ECM	299.8
		Q-Sync	328.1
	Walk-in	ECM	842.4
		Q-Sync	921.6

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
= 96.4%

Other variables as defined above.

For example, a display cooler with an ECM motor installed in place of a PSC motor, using the defaults above, would save:

$$\begin{aligned} \Delta kW &= (319.0/8760) * 0.964 \\ &= 0.0351 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY 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: NR-RFG-ECMF-V04-240101

SUNSET DATE: 1/1/2028

3.8.4. Night Covers for Open Refrigerated Display Cases

DESCRIPTION

This measure applies to the installation of retractable covers on existing open-type refrigerated and freezer display cases that are deployed during the facility unoccupied hours. Night covers are designed to reduce refrigeration energy consumption by reducing the work done by the compressor. Night covers reduce the heat and moisture entry into the refrigerated space through various heat transfer mechanisms. By fully or partially covering the case opening, night covers reduce the convective heat transfer into the case through reduced air infiltration. Additionally, they provide a measure of insulation, reducing conduction into the case, and also decrease radiation into the case by blocking radiated heat from entering the refrigerated space.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be retractable covers installed on existing open-type, commercial refrigerated or freezer display cases.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is existing open-type, commercial refrigerated or freezer display cases with no night covers installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 5 years, based on DEER 2014.⁷⁷⁷

DEEMED MEASURE COST

Actual equipment and labor costs should be used if available. In actual costs are unknown, assume a full installed cost of \$42 per linear foot of cover.⁷⁷⁸

LOADSHAPE

Loadshape NRE12: Night Covers for Refrigeration Display Cases

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$kWh = CaseFt * SavingsRate * Hours * Days$$

Where:

CaseFt = Width (ft) of the case opening protected by night cover
 = Actual

⁷⁷⁷ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

⁷⁷⁸ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.4 Night Covers for Open Refrigerated Display Cases

SavingsRate = Electric demand savings (kW/ft) from installing a night cover
 = Actual; or if unknown, use savings rate from table below depending on display case temperature:⁷⁷⁹

Display Case Temperature (°F)	SavingsRate (kW/ft)
Low (-35 to -5)	0.03
Medium (0 to 30)	0.02
High (35 to 55)	0.01

Hours = Number of hours per day that the night covers are in use
 = Actual or if unknown, use 6 hours per day⁷⁸⁰

Days = Number of days per year that night covers are in use
 = Actual or if unknown, use 365.25 days per year

For example, a low-temperature display case with night covers installed on a 12-foot wide opening, using the defaults above, would save:

$$\begin{aligned} \Delta kWh &= \text{CaseFt} * \text{SavingsRate} * \text{Hours} * \text{Days} \\ \Delta kWh &= 12 * 0.03 * 6 * 365.25 \\ &= 788.9 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Peak savings are null because savings occur at night only.

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: NR-RFG-NCOV-V03-240101

SUNSET DATE: 1/1/2025

⁷⁷⁹ "Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case." Southern California Edison Refrigeration Technology and Test Center Energy Efficiency Division, August 8, 1997.

⁷⁸⁰ Assumed 18-hour of uncovered operation of display case, based on a typical operating scenario from "Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case" Southern California Edison Refrigeration Technology and Test Center Energy Efficiency Division, August 8, 1997.

3.8.5. Refrigerated Beverage Vending Machine

DESCRIPTION

This measure applies to new ENERGY STAR Class A, Class B, Combination A, or Combination B refrigerated vending machines. A refrigerated beverage vending machine is a commercial refrigerator that cools bottled and/or canned beverages and dispenses the bottled and/or canned beverages (a beverage in a sealed container) on payment. ENERGY STAR vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as a low power mode option that allows the machine to be placed in low-energy lighting and/or low-energy refrigeration states during times of inactivity.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new or rebuilt ENERGY STAR Class A, Class B, Combination A, or Combination B refrigerated vending machine meeting energy consumptions requirements as determined by equipment type.

Class A Machine: A refrigerated bottled and/or canned beverage vending machine that is not a combination vending machine and in which 25 percent or more of the surface area on the front side of the beverage vending machine is transparent.

Class B Machine: Any refrigerated bottled and/or canned beverage vending machine not considered to be Class A, and is not a combination vending machine.

Combination Vending Machine: A bottled and/or canned beverage vending machine containing two or more compartments separated by a solid partition, that may or may not share a product delivery chute, in which at least one compartment is designed to be refrigerated, as demonstrated by the presence of temperature controls, and at least one compartment is not.

Combination A Machine: A combination vending machine where 25 percent or more of the surface area on the front side of the beverage vending machine is transparent.

Combination B Machine: A combination vending machine that is not considered to be Combination A.

ENERGY STAR Requirements (Version 4.0, Effective April 29, 2020)

Equipment Type	Maximum Daily Energy Consumption (kWh/day)
Class A	$\leq 0.04836V + 2.2599$
Class B	$\leq 0.04576V + 1.936$
Combination A	$\leq 0.07998V + 2.4738$
Combination B	$\leq 0.09768V + 1.7952$

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new or rebuilt, Class A, Class B, Combination A, or Combination B refrigerated vending machine that is not ENERGY STAR certified, but adheres to Federal Energy Conservation Standards.⁷⁸¹

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

⁷⁸¹ 10 CFR §431.296 (b) - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines. Effective for machines manufactured on or after January 8, 2019.

The expected measure life is assumed to be 10 years.⁷⁸²

DEEMED MEASURE COST

The incremental cost of this measure is \$199.⁷⁸³

LOADSHAPE

Loadshape NRE01 – Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below.

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

Where:

kWh_{Base} = Maximum daily energy consumption (kWh/day) of baseline vending machine
 = Calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWh_{Base} ⁷⁸⁴
Class A	$0.052V + 2.43$
Class B	$0.052V + 2.20$
Combination A	$0.086V + 2.66$
Combination B	$0.111V + 2.04$

kWh_{ESTAR} = Maximum daily energy consumption (kWh/day) of ENERGY STAR vending machine
 = Custom or if unknown, calculated as shown in the table below using the actual refrigerated volume (V)

Equipment Type	kWh_{EE} ⁷⁸⁵
Class A	$\leq 0.04836V + 2.2599$
Class B	$\leq 0.04576V + 1.936$
Combination A	$\leq 0.07998V + 2.4738$
Combination B	$\leq 0.09768V + 1.7952$

V = Refrigerated volume⁷⁸⁶ (ft³)

⁷⁸² Measure life from Final Report: Volume 2, Assessment of Energy and Capacity Savings Potential in Iowa: Appendices. The Cadmus Group, February 28, 2012

⁷⁸³ Incremental cost from Focus on Energy, Business Programs Incremental Cost Study, PA Consulting Group, October 28, 2009

⁷⁸⁴ 10 CFR §431.296 (b) - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines

⁷⁸⁵ ENERGY STAR Version 4.0 requirements for maximum daily energy consumption

⁷⁸⁶ V = the refrigerated volume (ft³) of the refrigerated bottled or canned beverage vending machine, as specified in Appendix C of the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 32.1 - 2010, "Methods of Testing for Rating Vending Machines for Bottled, Canned or Other Sealed Beverages." For combination vending machines, the refrigerated volume does not include any non-refrigerated compartments.

= Actual installed
 Days = Days of vending machine operation per year
 = 365.25 days per year

For example, an ENERGY STAR, Class A vending machine with a volume of 30 ft³ would save:

$$\begin{aligned} \Delta kWh &= (kWh_{\text{Base}} - kWh_{\text{ESTAR}}) * \text{Days} \\ \Delta kWh &= [(0.052 * 30 + 2.43) - (0.04836 * 30 + 2.2599)] * 365.25 \\ &= 102.0 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above
 Hours = Hours of vending machine operation per year
 = 8,760⁷⁸⁷
 CF = Summer peak coincidence factor
 = 96.4%⁷⁸⁸

For example, an ENERGY STAR vending machine with a volume of 30 ft³ would save:

$$\begin{aligned} \Delta kW &= (102 / 8,760) * 0.964 \\ &= 0.011 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY 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: NR-RFG-ESVE-V03-210101

SUNSET DATE: 1/1/2024*

* 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.

⁷⁸⁷ Equipment is assumed to operate continuously, 24 hour per day, 365.25 days per year

⁷⁸⁸ Based on modeling performed by VEIC of Grocery building type. This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

3.8.6. 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. Note that since both methods are based on residential units, this program is limited to residential-sized units in commercial settings. Furthermore, it is assumed that these retired units are not “secondary” units, but that the program is encouraging the early removal of inefficient units that are ultimately replaced.

The savings are equivalent to the Unit Energy Consumption of the retired unit minus an assumed baseline replacement unit (any additional savings attributed to purchasing a new high efficiency unit would be claimed through the Time of Sale measure) and should be claimed for the assumed remaining useful life of that unit. 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.

DEFINITION OF EFFICIENT EQUIPMENT

The existing inefficient refrigerator is removed from service and 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.⁷⁸⁹

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.⁷⁹⁰

LOADSHAPE

Loadshape RE09 - Residential Refrigerator

Loadshape RE02 – Residential Freezer

⁷⁸⁹ 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 (PY7-PY9) and Ameren (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.

⁷⁹⁰ 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:⁷⁹¹

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

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

Where:

- Age = Age of retired unit
- Pre-1990 = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)
- Size = Capacity (cubic feet) of retired unit
- Side-by-side = Side-by-side dummy (= 1 if side-by-side, else 0)
- Primary Usage = Primary Usage Type (in absence of the program) dummy
(= 1 if Primary, else 0)
- CDD = Cooling Degree Days
= Dependent on location:⁷⁹²

Climate Zone (City based upon)	GHCNd ID	Official Name	CDD 65	CDD 65 / 365.25
Zone 5 (Burlington)	USC00131060	BURLINGTON 2S, IA US	1,105	3.03

⁷⁹¹ 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.

⁷⁹² 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 / 365.25
Zone 6 (Mason City)	USW00014940	MASON CITY MUNI AP, IA US	644	1.76
Average (Des Moines)	USW00014933	DES MOINES INTL AP, IA US	1,134	3.10

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

HDD = Heating Degree Days
 = Dependent on location:⁷⁹³

Climate Zone (City based upon)	GHCNd ID	Official Name	HDD 60	HDD 60 / 365.25
Zone 5 (Burlington)	USC00131060	BURLINGTON 2S, IA US	4,832	13.23
Zone 6 (Mason City)	USW00014940	MASON CITY MUNI AP, IA US	6,356	17.40
Average (Des Moines)	USW00014933	DES MOINES INTL AP, IA US	5,013	13.72

UEC_{BaseRefrig} = Assumed consumption of a new baseline residential-sized refrigerator
 = 558.3 kWh⁷⁹⁴

Deemed Approach: Refrigerators

$$\Delta kWh_{Unit} = UEC_{Retired} - UEC_{BaseRefrig}$$

Where:

UEC_{Retired} = Unit Energy Consumption of retired unit based on Mid American and Alliant 2019 and 2020 program data⁷⁹⁵:

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

= Dependent on climate zone as provided in table below.

Deemed refrigerator savings are provided below:

⁷⁹³ National Climatic Data Center, Annual Normals calculated by NCDC, 15-year span from 2006-2020, with a base temp of 60°F.

⁷⁹⁴ Consistent with Residential Refrigerator measure (based on applying the Federal Standard algorithms for the common configuration types and applying market weighting). Note that the baseline is used here as any additional delta between baseline and high efficient units will be captured through the Time of Sale measure.

⁷⁹⁵ See IA Refrig Freezer Recycling Excel Analysis File for details.

Climate Zone (City based upon)	UEC	ΔkWh per unit
5 (Burlington)	944.9	301.6
6 (Mason City)	903.9	264.3
Average (Des Moines)	942.2	299.1

Regression Analysis: Freezers

Energy savings for freezers are based upon a linear regression model using the following coefficients:⁷⁹⁶

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

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

Where:

- Age = Age of retired unit
- Pre-1990 = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)
- Size = Capacity (cubic feet) of retired unit
- Chest Freezer = Chest Freezer dummy (= 1 if chest freezer, else 0)
- CDD = Cooling Degree Days (see table in refrigerator section)
- Unconditioned = If unit in unconditioned space = 1, otherwise 0
- HDD = Heating Degree Days (see table in refrigerator section)
- UEC_{BaseFreezer} = Assumed consumption of a new baseline residential sized freezer = 381.2 kWh⁷⁹⁷

Deemed Approach: Freezers

$$\Delta kWh_{unit} = UEC_{Retired} - UEC_{BaseFreezer}$$

⁷⁹⁶ 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.

⁷⁹⁷ Consistent with Residential Freezer measure (based on applying the Federal Standard algorithms for the common configuration types and applying market weighting). Note that the baseline is used here as any additional delta between baseline and high efficient units will be captured through the Time of Sale measure.

Where:

$UEC_{Retired}$ = Unit Energy Consumption of retired unit based on Mid American and Alliant 2019 and 2020 program data⁷⁹⁸;

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/365.25	0.83

Deemed freezer savings are provided below:

Climate Zone (City based upon)	UEC	ΔkWh per unit
5 (Burlington)	950.4	436.1
6 (Mason City)	896.2	389.5
Average (Des Moines)	945.8	432.2

Additional Waste Heat Impacts⁷⁹⁹

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

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

Where:

Conditioned = % of units in conditioned space
 = 100% if unit in conditioned space, 0% if unit in unconditioned space,
 = If unknown assume unit is in conditioned space – 100%

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

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

$$= - (HF / \eta_{HeatElectric}) * \%ElecHeat$$

HF = Heating Factor or percentage of reduced waste heat that must now be heated
 = 52% for unit in heated space⁸⁰⁰
 = 0% for unit in heated space

$\eta_{HeatElectric}$ = Efficiency in COP of Heating equipment

⁷⁹⁸ See IA Refrig Freezer Recycling Excel file for details.

⁷⁹⁹ The waste heat impacts are relatively small, and with the absence of any clear data on the types of buildings these non-residential units are being removed from, residential assumptions are provided as a reasonable proxy.

⁸⁰⁰ Based on 190 days where HDD 55>0, divided by 365.25. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

= Actual - If not available, use:⁸⁰¹

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.38 ⁸⁰²

%ElecHeat = Percentage of businesses with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	30% ⁸⁰³

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

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

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

= 35% for unit in cooled space⁸⁰⁴

= 0% for unit in uncooled space

ηCool = Efficiency in COP of Cooling equipment

= Actual - If not available, assume 2.8 COP⁸⁰⁵

%Cool = Percentage of businesses with cooling

AC use	%Cool
Cooling	100%
No Cooling	0%
Unknown	74% ⁸⁰⁶

⁸⁰¹ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 and 2015 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

⁸⁰² 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 assumptions for small commercial buildings are expected to be similar to assumptions for residential buildings.

⁸⁰³ Based on data for the Midwest, West North Central census division from Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey, Table B28 (Primary Space-Heating Energy Sources, Number of Buildings).

⁸⁰⁴ Based on 128 days where CDD 65>0, divided by 365.25. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

⁸⁰⁵ Starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm $(-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$ (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

⁸⁰⁶ Based on data for the Midwest, West North Central census division from Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey, Table B30 (Cooling Energy Sources, Number of Buildings and Floorspace).

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta kWh_{WasteHeat}$
Refrigerator	5 (Burlington)	-6.2
	6 (Mason City)	-5.4
	Average (Des Moines)	-6.1
Freezer	5 (Burlington)	-9.0
	6 (Mason City)	-8.0
	Average (Des Moines)	-8.9

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.⁸⁰⁷

Refrigerator Location	WHFdCool
Cooled space	1.29 ⁸⁰⁸
Uncooled	1.0

CF = Coincident factor as calculated using eShapes loadprofile

Refrigerators = 70.9%

Freezers = 95.3%

Deemed approach: Refrigerators

Climate Zone (City based upon)	ΔkW per unit
5 (Burlington)	0.0387
6 (Mason City)	0.0339
Average (Des Moines)	0.0383

Deemed approach: Freezers

Climate Zone	ΔkW
--------------	-------------

⁸⁰⁷ The waste heat impacts are relatively small, and with the absence of any clear data on the types of buildings these non-residential units are being removed from – the Residential assumptions are provided as a reasonable proxy.

⁸⁰⁸ The value is estimated at 1.29 (calculated as 1 + (0.798 / 2.8)). See footnote relating to WHFe for details. Note the 79.8% factor represents the non-residential average cooling coincidence factor.

(City based upon)	per unit
5 (Burlington)	0.0673
6 (Mason City)	0.0601
Average (Des Moines)	0.0667

NATURAL GAS SAVINGS

Heating penalty for reduction in waste heat, only for retired units from conditioned space in gas heated businesses (if unknown, assume unit is from conditioned space).⁸⁰⁹

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

Where:

- ΔkWh_{Unit} = kWh savings calculated from either method above, not including the $\Delta kWh_{WasteHeat}$
- WHFeHeatGas = Waste Heat Factor for Energy to account for gas heating increase from removing waste heat from refrigerator/freezer
- = - (HF / $\eta_{HeatGas}$) * %GasHeat

Where:

- HF = Heating Factor or percentage of reduced waste heat that must now be heated
- = 52% for unit in heated space⁸¹⁰
- = 0% for unit in unheated space
- $\eta_{HeatGas}$ = Efficiency of heating system
- = Actual, if unknown assume 74%⁸¹¹
- %GasHeat = Percentage of businesses with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	70% ⁸¹²

0.03412 = Converts kWh to Therms

Deemed waste heat impacts are provided below:

⁸⁰⁹ The waste heat impacts are relatively small. And with the absence of any clear data on the types of buildings these non-residential units are being removed from, the Residential assumptions are provided as a reasonable proxy.

⁸¹⁰ Based on 190 days where HDD 55>0, divided by 365.25. NCDL US Climate Hourly Normals 15 yr (2006-2020).

⁸¹¹ This has been estimated assuming that natural gas central furnace heating is typical for Iowa residences (the predominant heating is gas furnace with 49% of Iowa homes - based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 60% of furnaces purchased in Iowa were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 15 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.60*0.92) + (0.40*0.8)) * (1-0.15) = 0.74. Heating assumptions for small commercial buildings are expected to be similar to assumptions for residential buildings.

⁸¹² Based on data for the Midwest, West North Central census division from Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey, Table B28 (Primary Space-Heating Energy Sources, Number of Buildings).

Unit Type	Climate Zone (City based upon)	$\Delta\text{Therms}_{\text{WasteHeat}}$
Refrigerator	5 (Burlington)	-5.1
	6 (Mason City)	-4.4
	Average (Des Moines)	-5.0
Freezer	5 (Burlington)	-7.3
	6 (Mason City)	-6.5
	Average (Des Moines)	-7.3

PEAK GAS SAVINGS

Heating penalty for reduction in waste heat, only for retired units from conditioned space in gas heated businesses

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

= 190⁸¹³

Deemed waste heat impacts are provided below:

Unit Type	Climate Zone (City based upon)	$\Delta\text{PeakTherms}$
Refrigerator	5 (Burlington)	-0.0266
	6 (Mason City)	-0.0233
	Average (Des Moines)	-0.0264
Freezer	5 (Burlington)	-0.0385
	6 (Mason City)	-0.0344
	Average (Des Moines)	-0.0382

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-REF-RFRC-V04-240101

SUNSET DATE: 1/1/2026

⁸¹³ Number of days where HDD 55 >0. Calculated from NCDC 15-yr US Climate Hourly Normals, for Des Moines (2006-2020).

3.8.7. Scroll Refrigeration Compressor

DESCRIPTION

This measure applies to scroll refrigerant compressors utilized in commercial refrigeration including supermarkets, foodservices, and convenience store applications.⁸¹⁴ Supermarket refrigeration systems typically operate at two temperatures, medium and low. Medium temperatures are typically used for walk-in coolers where as low-temperature cases are used for walk-in freezers.

Scroll compressors have fewer moving parts than reciprocating compressors and as such operate more smoothly, quietly, and continuously.⁸¹⁵ In addition the scroll compressor design allows them to be nearly 100% volumetrically efficient in pumping the trapped fluid.

This measure applies to one-for-one replacement of 1 to 10 horsepower refrigeration compressors and was developed to be applicable to retrofit (RF) opportunities only where an existing reciprocating compressor is being replaced with an equivalent efficient refrigeration scroll compressor.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient system is assumed to be a scroll refrigeration compressor replacing a reciprocating compressor.⁸¹⁶

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be the existing reciprocating compressor.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for scroll compressors is 12 years.⁸¹⁷

DEEMED MEASURE COST

As a retrofit measure, when available, the actual cost of the measure installation and equipment shall be used. For a default range, see the incremental capital cost listed in the reference table.

LOADSHAPE

Loadshape NRE01 - Non-Residential Refrigeration – Grocery

⁸¹⁴ Scroll compressors using R22 refrigerant are not eligible for this measure. In 2012 the U.S. government enacted a policy requiring all air conditioners and heat pumps no longer use the ozone-depleting R22 refrigerant (AC Freon). See ozone layer protection regulatory programs under www.epa.gov for more information.

⁸¹⁵ Reciprocating compressors have multiple cylinders while scroll compressors only have one compression element made up of two identical, concentric scrolls, one inserted within the other. One scroll remains stationary as the other orbits around it. This movement draws gas into the compression chamber and moves it through successively smaller pockets formed by the scroll's rotation, until it reaches maximum pressure at the center of the chamber. At this point, the required discharge pressure has been achieved. There, it is released through a discharge port in the fixed scroll. During each orbit, several pockets are compressed simultaneously, making the operation continuous – this factor also reduces pulsation levels – lower sound, vibration of attached piping.

⁸¹⁶ Following the expansion of highly efficient motors rules effective March 2015, the US DOE Code of Federal Regulations also regulates and has appliance/code standards for the efficiency level of pumps, fans and compressors in order to improve overall system efficiency. The final ruling for compressors and walk-in coolers/freezers refrigeration systems was made effective in September 2017 with compliance required on July 10, 2020.

⁸¹⁷ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.5, “Effective/Remaining Useful Life Values”, California Public Utilities Commission. See “DEER2014-EUL-table-update_2014-02-05.xlsx”.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{\left((Avg\ Cap * FLH) * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right) \right)}{1000} * units$$

Where:

- Avg Cap = Compressor average capacity in Btu/h. See reference table for values. For prescriptive measures the average capacity for each range of size is used.⁸¹⁸
- EER_{base} = Cooling efficiency of existing compressor in Btu/watt-hour. See reference tables for values.
- EER_{ee} = Cooling efficiency of efficient scroll compressor in Btu/watt-hour. See reference tables for values.
- FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are as follows for the different refrigeration temperature applications.⁸¹⁹

Refrigeration Application	Full Load Hours
Medium Temperature	3,910
Low Temperature	4,139

- Units = Number of units
- = Actual number of units installed

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- kW = gross customer connected load kW savings for the measure (kW)
- FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are 3,910 hours for medium temperature applications and 4,139 hours for low temperature applications.⁸²⁰
- CF = System Peak Coincidence Factor. Assume non-residential average of 96.4%.

NATURAL GAS ENERGY SAVINGS

N/A

⁸¹⁸ Given this measure characterizes 1.5-10 HP the BTU/hr range is calculated as 1 Btu/Hr to Horsepower = 0.0004. This presenting a valid range of 1- 25199 BTU/hr for Avg. Cap.

⁸¹⁹ Based on run time estimates from “Performance Standards for Walk-In Refrigerator and Freezer Systems,” AHRTI Report No. 09002-01, by Bryan R. Becker, et al., January 2012, Tables 30-33.

⁸²⁰ Based on run time estimates from “Performance Standards for Walk-In Refrigerator and Freezer Systems,” AHRTI Report No. 09002-01, by Bryan R. Becker, et al., January 2012, Tables 30-33.

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES⁸²¹

Baseline and Qualifying EER Values by Capacity and Temperature Application⁸²²

Low Temperature Cases			
Baseline and Qualifying EER			
Condensing Temp 90°F, Evaporating Temp -25°F			
Capacity Bins in BTU/Hr	HP equivalent ⁸²³	Average EER _{base}	Average EER _{ee}
0-4,200	1	3.85	4.39
4,200-8,399	2	4.83	5.21
8,400-12,599	3	5.06	5.37
12,600-16,799	4	5.26	5.59
16,800-20,999	5	5.36	5.80
21,000-25,199	6	5.69	6.06
25,200-29,399	7	5.71	6.15
29,400-33,599	8	6.14	6.39
33,600-37,800	9	5.64	6.06
37,800-42,000	10	5.73	6.06

Medium Temperature Cases			
Baseline and Qualifying EER			
Condensing Temp 90°F, Evaporating Temp 20°F			
Capacity Bins in BTU/Hr	HP equivalent	Average EER _{base}	Average EER _{ee}
0-7,500	1	8.14	9.03
7,500-14,999	2	9.28	10.86
15,000-22,499	3	10.64	11.83

⁸²¹ Baseline EERs and Qualifying EERs calculations come from available modeling and installation data provided by Efficiency Vermont referred in the 2014 TRM and supported by referenced document “TRM compressor efficiency analysis.xlsx” for averaging of data for IA TRM.

⁸²² Supermarket refrigeration systems typically operate at two evaporator temperatures, medium temperature and low temperature. Medium temperature cases vary from 10°F to 35°F with a typical mean evaporating temperature of 20°F. Medium temperature cases are typically used for meats, dairy, beverages and walk-in coolers. Low-temperature cases vary from -15°F to -25°F and are used for frozen foods, ice cream, and walk-in freezers. A typical mean low temperature evaporating temperature is -25°F.

⁸²³ At low temperatures the standard calculation for Compressor HP vs. Btu/Hr is 4,226 Btu/hr per HP. Round numbers to 4,200 for ease of binning.

Medium Temperature Cases			
Baseline and Qualifying EER			
Condensing Temp 90°F, Evaporating Temp 20°F			
Capacity Bins in BTU/Hr	HP equivalent	Average EER _{base}	Average EER _{ee}
22,500-29,999	4	11.18	12.15
30,000-37,499	5	11.12	12.39
37,500-44,999	6	11.74	12.70
45,000-52,499	7	11.68	12.52
52,500-59,999	8	12.54	13.12
60,000-67,499	9	12.46	13.13
67,500-75,000	10	11.44	12.37

MEASURE CODE: MEASURE CODE: NR-RFG-SCR-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.

3.8.8. Strip Curtain for Walk-in Coolers and Freezers

DESCRIPTION

This measure applies to the installation of infiltration barriers (strip curtains) on walk-in coolers or freezers. Strip curtains impede heat transfer from adjacent warm and humid spaces into walk-ins when the main door is opened, thereby reducing the cooling load. As a result, compressor run time and energy consumption are reduced.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a strip curtain added to a walk-in cooler or freezer.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a walk-in cooler or freezer that previously had no strip curtain installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 4 years.⁸²⁴

DEEMED MEASURE COST

Actual equipment and labor costs should be used if available. In actual costs are unknown, assume a full installed cost of \$10.22 per square foot.⁸²⁵

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below,⁸²⁶ otherwise use deemed values within the table that follows:

$$kWh = \left(\left(\frac{Q_{Base}}{EER \times 1000} \right) - \left(\frac{Q_{EE}}{EER \times 1000} \right) \right) \times EFLH / A \times A$$

Where:

- Q_{Base} = Total infiltration load (Btu/hr) of cooler or freezer with no strip curtain installed
= Use value from table below as determined by building type
- Q_{EE} = Total infiltration load (Btu/hr) of cooler or freezer with strip curtain installed

⁸²⁴ DEER 2014 Effective Useful Life

⁸²⁵ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”, California Public Utilities Commission, December 16, 2008.

⁸²⁶ Algorithms and assumptions from Regional Technical Forum (RTF) Unit Energy Savings (UES) Measures and Supporting Documentation: Grocery – Strip Curtains v.1.4

= 561 Btu/hr for coolers and 898 Btu/hr for freezers

	Grocery Store		Restaurant		Convenience Store		Unknown Building Type	
	Cooler	Freezer	Cooler	Freezer	Cooler	Freezer	Cooler	Freezer
Q _{Base}	4,661	7,464	1,054	2,136	895	485	2,012	3,128
Q _{EE}	559	896	211	406	188	82	355	500

EER = Energy efficiency ratio of cooler or freezer
 = Custom or if unknown, use value from table below as determined by building type

	Grocery Store		Restaurant or Convenience Store		Unknown Building Type	
	Cooler	Freezer	Cooler	Freezer	Cooler	Freezer
EER	10.6	4.1	9.8	4.0	10.2	4.0

1,000 = Conversion factor from watts to kilowatts
 EFLH = Equivalent full load hours of cooler or freezer
 = Custom or if unknown, use 7,693 for coolers and 8,121 for freezers
 A = Area (ft²) of cooler or freezer covered by strip curtains
 = Custom or if unknown, assume 21 ft²

For example, a cooler with strip curtains installed at a grocery store, using the defaults from above, would save:

$$\Delta kWh = ((Q_{Base}/EER \times 1000) - (Q_{EE}/EER \times 1000)) \times EFLH/A \times A$$

$$\Delta kWh = ((4,661/10.6 \times 1000) - (559/10.6 \times 1000)) \times 7,693/21 \times 21$$

$$= 2,977.0 \text{ kWh}$$

Savings for grocery stores, restaurants, convenient stores, and unknown building types are presented in the table below.⁸²⁷

	Grocery Store		Restaurant		Convenience Store		Unknown Building Type	
	(kWh/ft ²)	(kWh/Case)	(kWh/ft ²)	(kWh/Case)	(kWh/ft ²)	(kWh/Case)	(kWh/ft ²)	(kWh/Case)
Cooler	142.3	2,988.1	31.4	659.9	26.3	553.2	59.5	1,249.7
Freezer	619.3	13,005.4	168.1	3,529.1	39.1	820.9	251.4	5,278.9

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh/EFLH) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above
 CF = Summer peak coincidence factor

⁸²⁷ Savings for unknown building types represent the average of grocery store, restaurant, and convenience store savings.

= 96.4%

Other variables as defined above.

For example, a cooler with strip curtains installed at a restaurant, using the defaults above, would save:

$$\begin{aligned}\Delta kW &= (2,977.0/7,693) * 0.964 \\ &= 0.3730 \text{ kW}\end{aligned}$$

NATURAL GAS ENERGY 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: NR-RFG-STCR-V03-190101

SUNSET DATE: 1/1/2021*

* 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.

3.8.9. Ice Maker

DESCRIPTION

This measure relates to the installation of a new ENERGY STAR certified commercial ice maker. The ENERGY STAR label applies to air-cooled, batch-type and continuous-type machines including ice-making head (IMH), remote-condensing units (RCU), and self-contained units (SCU). ENERGY STAR ice makers are approximately 15% more efficient than standard ice makers.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the efficient equipment must be an ENERGY STAR certified commercial ice maker meeting energy consumption rate and potable water use limits, as determined by equipment type and for batch-type ice makers, ice harvest rate range.⁸²⁸

ENERGY STAR Requirements (Version 3.0, Effective January 28, 2018)

ENERGY STAR Requirements for Air-Cooled Batch-Type Ice Makers			
Equipment Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	ENERGY STAR Energy Consumption Rate (kWh/100 lbs ice)	Potable Water Use (gal/100 lbs ice)
IMH	H < 300	≤ 9.20 - 0.01134H	≤ 20.0
	300 ≤ H < 800	≤ 6.49 - 0.0023H	
	800 ≤ H < 1500	≤ 5.11 - 0.00058H	
	1500 ≤ H ≤ 4000	≤ 4.24	
RCU	H < 988	≤ 7.17 - 0.00308H	≤ 20.0
	988 ≤ H ≤ 4000	≤ 4.13	
SCU	H < 110	≤ 12.57 - 0.0399H	≤ 25.0
	110 ≤ H < 200	≤ 10.56 - 0.0215H	
	200 ≤ H ≤ 4000	≤ 6.25	
ENERGY STAR Requirements for Air-Cooled Continuous-Type Ice Makers			
Equipment Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	ENERGY STAR Energy Consumption Rate (kWh/100 lbs ice)	Potable Water Use (gal/100 lbs ice)
IMH	H < 310	≤ 7.90 - 0.005409H	≤ 15.0
	310 ≤ H < 820	≤ 7.08 - 0.002752H	
	820 ≤ H ≤ 4000	≤ 4.82	
RCU	H < 800	≤ 7.76 - 0.00464H	≤ 15.0
	800 ≤ H ≤ 4000	≤ 4.05	
SCU	H < 200	≤ 12.37 - 0.0261H	≤ 15.0
	200 ≤ H < 700	≤ 8.24 - 0.005429H	
	700 ≤ H ≤ 4000	≤ 4.44	

DEFINITION OF BASELINE EQUIPMENT

⁸²⁸ ENERGY STAR Commercial Ice Makers Version 3.0, January 28th, 2018

The baseline equipment is a new commercial ice maker that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.⁸²⁹

DEEMED MEASURE COST

When available, the actual cost of the measure installation and equipment shall be used. The incremental capital cost for this measure is \$250 for Batch-Type and \$250 for Continuous-Type ice makers.⁸³⁰

LOADSHAPE

Loadshape NRE01 - Nonresidential Electric Refrigeration – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed values from the table that follows.⁸³¹

$$\Delta kWh = \left[\frac{(kWh_{Base} - kWh_{ESTAR})}{100} \right] * (Duty * H) * Days$$

Where:

- kWh_{Base} = Energy consumption rate (kWh / 100 pounds of ice) of baseline ice maker
= Calculated as shown in the table below using the ice harvest rate (H)
- kWh_{ESTAR} = Energy consumption rate (kWh / 100 pounds of ice) of ENERGY STAR ice maker
= Calculated as shown in the table below using the ice harvest rate (H)

⁸²⁹Measure life from ENERGY STAR Commercial Food Service Savings Calculator updated July 15th, 2021x

⁸³⁰Incremental costs from ENERGY STAR Commercial Food Service Savings Calculator updated July 15th, 2021. Calculator cites EPA research using AutoQuotes, October 2020.

⁸³¹ Algorithms and assumptions derived from ENERGY STAR Commercial Food Service Savings Calculator updated October July 15th, 2021

Energy Consumption of Air-Cooled Batch-Type Ice Makers			
Ice Maker Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	kWh _{Base}	kWh _{ESTAR}
IMH	H < 300	10-0.01233H	≤ 9.20 - 0.01134H
	300 ≤ H < 800	7.05-0.0025H	≤ 6.49 - 0.0023H
	800 ≤ H < 1500	5.55-0.00063H	≤ 5.11 - 0.00058H
	1500 ≤ H ≤ 4000	4.61	≤ 4.24
RCU	H < 988	7.97-0.00342H	≤ 7.17 – 0.00308H
	988 ≤ H ≤ 4000	4.59	≤ 4.13
SCU	H < 110	14.79-0.0469H	≤ 12.57 - 0.0399H
	110 ≤ H < 200	12.42-0.02533H	≤ 10.56 - 0.0215H
	200 ≤ H ≤ 4000	7.35	≤ 6.25
Energy Consumption of Air-Cooled Continuous-Type Ice Makers			
Equipment Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	kWh _{Base}	kWh _{ESTAR}
IMH	H < 310	9.19-0.00629H	≤ 7.90 – 0.005409H
	310 ≤ H < 820	8.23-0.0032H	≤ 7.08 – 0.002752H
	820 ≤ H ≤ 4000	5.61	≤ 4.82
RCU	H < 800	9.7-0.0058H	≤ 7.76 – 0.00464H
	800 ≤ H ≤ 4000	5.06	≤ 4.05
SCU	H < 200	14.22-0.03H	≤ 12.37 – 0.0261H
	200 ≤ H < 700	9.47-0.00624H	≤ 8.24 – 0.005429H
	700 ≤ H ≤ 4000	5.1	≤ 4.44

- 100 = Factor to convert kWh_{Base} and kWh_{ESTAR} into energy consumption per pound of ice
- Duty = Duty cycle (%) of ice maker
 - = Custom or if unknown, use 0.75
- H = Ice harvest rate (pounds of ice/day)
 - = Custom or if unknown, use value from table below as determined by equipment type

Ice Harvest Rate (H) of Air-Cooled Batch-Type Ice Makers		
IMH	RCU	SCU
650	1,150	170
Ice Harvest Rate (H) of Air-Cooled Continuous-Type Ice Makers		
IMH	RCU	SCU
680	1,170	240

- Days = Annual days of operation
 - = Custom or if unknown, use 365.25 days per year

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

$$\begin{aligned} \Delta kWh &= [((7.05 - 0.0025 * 650) - (6.49 - 0.0023 * 650)) / 100] * (0.75 * 650) * 365.25 \\ &= [((5.425) - (4.995)) / 100] * (0.75 * 650) * 365.25 \\ &= 765.7 \text{ kWh} \end{aligned}$$

Savings for all ice maker types are presented in the table below.

Energy Consumption of Air-Cooled Batch-Type Ice Makers			
Ice Maker Type	kWh _{Base}	kWh _{ESTAR}	Savings (kWh)
IMH	9,659.7	8,894.1	765.7
RCU	14,459.8	13,010.7	1,449.1
SCU	3,778.6	3,215.6	563.0
Energy Consumption of Air Cooled Continuous-Type Ice Makers			
Ice Maker Type	kWh _{Base}	kWh _{ESTAR}	Savings (kWh)
IMH	11,277.2	9,702.5	1,574.7
RCU	16,217.6	12,980.5	3,237.1
SCU	5,241.5	4,560.8	680.7

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- Hours = Average daily hours of operation
= Custom or if unknown, use 12 hours per day
- CF = Summer peak coincidence factor
= 96.4%

Other variables as defined above.

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

$$\begin{aligned} \Delta kW &= 765.7 / (12 * 365.25) * 0.964 \\ &= 0.1684 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

While the ENERGY STAR labeling criteria require that certified commercial ice machines meet certain “maximum potable water use per 100 pounds of ice made” requirements, such requirements are intended to prevent equipment manufacturers from gaining energy efficiency at the cost of water consumptions. A review of the AHRI Certification Directory indicates that all of air-cooled, cube-type machines meet the ENERGY STAR potable water use requirement.⁸³² Therefore, there are no assumed water impacts for this measure.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ESIM-V03-240101

SUNSET DATE: 1/1/2028

⁸³² AHRI Certification Directory, Accessed on 3/14/2023

3.8.10. Efficient Motor Controls for Walk-In and Display Case Coolers/Freezers

DESCRIPTION

This measure is for the installation of controls for efficient motors – defined as electrically commutated motors (ECM) or Q-Sync motors, per measure 3.8.3 – in existing walk-in and display case coolers or freezers. The controller reduces airflow of the evaporator fans when there is no refrigerant flow.

This measure achieves savings by controlling the motor(s) to run at lower speeds (or shut off entirely) when there is no refrigerant flow, the result of which produces less waste heat that the cooling system must reject.

If eligible, this measure may be claimed in combination with 3.8.3 Efficient Motor for Walk-in and Display Case Coolers / Freezers.

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 measure must control a minimum of 16 Watts where fans operate continuously at full speed. This measure is limited to motors that are rated equal to or less than 3/4 HP output capacity. The measure also must reduce fan motor power by at least 75% during the off cycle. This measure is not applicable if any of the following conditions apply:

- The compressor runs more than 4380 hours annually
- The evaporator fan does not run at full speed all the time
- The evaporator fan motor runs on poly-phase power
- Evaporator does not use off-cycle or time-off defrost.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the existing condition must be a reach-in or walk-in freezer or cooler with continuously running evaporator fans driven by electrically commutated motors (ECM) or Q-Sync motors.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.⁸³³

DEEMED MEASURE COST

The measure cost is assumed to be \$69.69 (controller equipment) plus \$92.06 (controller labor) = \$161.75 per motor controlled.⁸³⁴

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

⁸³³ Average EUL from DEER 2014 Analysis, Energy & Resource Solutions (ERS) 2005 Measure Life Study, and ComEd 2018 Effective Useful Life Research Report

⁸³⁴ DEER Work Paper PGE3PREF126 ECM for Walk-In Evaporator with Fan Controller

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.10 Efficient Motor Controls for Walk-In and Display Case Coolers/Freezers

Savings are estimated using a trend fit based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association⁸³⁵ and supported by a PGE workpaper. Note that climate differences across all California climate zones result in negligible savings differences, which indicates that the average savings for the California study should apply equally as well to Iowa. Savings found in the aforementioned source are presented in combination with savings from an ECM upgrade, however for the purposes of this measure only those associated with the controller are considered.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((5988.5 * kW_{Output}) + 63.875) * \#Motors$$

Where:

- kW_{Output} = Output wattage of installed fan motor, in kW
(From linear trend line where 5988.5 = kWh savings/ kW_{Output} , and 63.875 = kWh savings at 0 kW_{Output})
= Actual or if unknown, use 0.01495 kW⁸³⁶
- $\#Motors$ = number of fan motors controlled

For example, a cooler with ECM motor controls for three 0.15 kW evaporator fans would save:

$$\begin{aligned} \Delta kWh &= ((5988.5 * kW_{Output}) + 63.875) * \#Motors \\ \Delta kWh &= ((5988.5 * 0.15) + 63.875) * 3 \\ &= 2886.5 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- Hours = Annual hours of cooler or freezer operation
= Assume 8,760 hours
- CF = Summer peak coincidence factor
= 96.4%⁸³⁷

For example, a cooler with ECM motor controls for three 0.15 kW evaporator fans would save:

$$\begin{aligned} \Delta kW &= (\Delta kWh/Hours) * CF \\ \Delta kW &= ((2886.5/8766) * 0.964 \\ &= 0.32 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

⁸³⁵ See '3.8.10_Ver8_Evap Fan Control Analysis.xlsx'.

⁸³⁶ Weighted average of output motor wattages from invoices submitted to EnergySmart Grocer program. RTF Unit Energy Savings (UES) Measures and Supporting Documentation: Grocery - ECMs for Display Cases v.3.1.

⁸³⁷ Based on modeling performed by VEIC of Grocery building type. This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.10 Efficient Motor Controls for Walk-In and Display Case Coolers/Freezers

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ECMC-V02-240101

SUNSET DATE: 1/1/2025

3.8.11. Adding Doors to Open Refrigeration Display Cases

DESCRIPTION

Open display cases are typically found in grocery and convenience stores and have been a preference of store owners because they allow customers a clear view and easy access to refrigerated products. This measure is retrofitting existing, open, refrigerated display cases by adding and installing doors. The baseline equipment is an open vertical or horizontal display case with no doors or covering. The efficient equipment is the installation of solid doors on the existing display case. Replacement of open display cases with new display cases with doors is not covered under this measure characterization.

Energy savings are based on air infiltration reduction from the addition of doors to the open display cases. The air infiltration reductions assume a reduced heat gain and subsequent reduced load on the refrigeration compressors. Both radiant and conduction heat losses were factored into the analysis as well. Energy savings are based on a per linear foot of display case.

Interactive HVAC energy savings were also included in the measure savings analysis. The HVAC interactive effects calculation assesses the measure's impact on the heating and cooling equipment. With adding a door to an open refrigerated display case, excess cold air leaking into the conditioned space no longer has to be treated by the heating system, resulting in additive savings. Similarly, the reduction in cold air from the open refrigerated display case no longer supplements the efforts of the space cooling equipment, which results in an overall increase in its consumption.

High, medium, and low temperature cases are eligible for this measure; however, the measure assumptions detailed in this characterization are based on medium temperature display cases, with the installation of zero energy doors, as it was deemed the most likely candidate for participation in this measure.

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 retrofitting an existing open, refrigerated, display case by adding doors.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is an open, refrigerated, display case without any covering.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 12 years.⁸³⁸

DEEMED MEASURE COST

The incremental cost, which includes both material and labor, is \$522 per linear foot.⁸³⁹

LOADSHAPE

⁸³⁸ The measure life is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases – PGE3PREF116", April 2014

⁸³⁹ The incremental cost is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases – PGE3PREF116", April 2014

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Loadshape NREC01:16 - Nonresidential Cooling (by Building Type)

Loadshape NRGH01:16 – Nonresidential Gas Heating (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((\Delta HG * CL) / (EER * 1000)) * 8760 + (MMBtu_{HVAC\ Cool} * CL * (1 / SEER) * 1000)$$

Where:

- ΔkWh = gross customer annual kWh savings
- ΔHG = Heat Gain, the decreased load or the reduced heat gain on the open refrigerated display case with the installation of a door (Btu/hr-linear foot)
= 1,148 Btu/h-ft⁸⁴⁰
- CL = Case Length, refrigerated case length in feet
= Actual
- EER = Energy Efficiency Ratio; display case compressor efficiency (Btu/hr-watt)
= Actual. If unknown, use 11.36⁸⁴¹
- 1000 = Conversion from watts to kilowatts (W / kW)
- 8760 = Annual operating hours of the refrigerated display case⁸⁴²
- MMBtu_{HVAC Cool} = Total cooling load increase on the HVAC equipment per linear foot of display case
= -2.789 MMBtu/ft⁸⁴³

⁸⁴⁰ The change in heat gain is sourced as the typical value for a medium temperature display case adding doors from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases - PGE3PREF116", April 2014. The workpaper assumes a net reduction in heat gain with the installation of doors on open refrigerated display cases. The primary benefits account for the decrease in excess heat entering the display case from air infiltration. Radiation and conduction heat gains were also included in the derivation of this value. Additionally, the net heat gain has built in assumptions on how often the refrigerated case doors will be used and the display case accessed by customers and site associates, reducing some of the air infiltration benefits of the new door.

⁸⁴¹ Average EER values were calculated as the average of standard reciprocating and discus compressor efficiencies, using a typical condensing temperature of 90°F and saturated suction temperatures (SST) of 20°F for medium temperature applications. The efficiency analysis and product review is sourced from the Efficiency Vermont TRM, which utilizes data from Emerson Climate Technology software. Medium temperature cases have an EER value of 11.36.

⁸⁴² The measure assumes the baseline equipment is not employing night covers or any other covering but is in fact left open for the duration of its operation.

⁸⁴³ The MMBtu increase on the HVAC cooling equipment is based on an outdoor air temperature bin analysis, the total hours of operation of the cooling system, and the building's overall loss of additional cooling as a result of the installation of the doors on the open refrigerated display case. The analysis assumes a certain amount of conditioned air has to be treated to replace the air previously cooled by the display case. Furthermore, the analysis assumes an increased load on the cooling system, at outdoor temperatures above 62.5°F. A 25% disabling factor was also applied to account for some of the cold air pouring out of the display case and subcooling the site's conditioned space, which will not trigger a thermostatic response from the HVAC equipment. For more information on the analysis used to derive the load increase on the HVAC cooling equipment per linear foot of display case, please see the 'HVAC IE' tab in the "IA TRM_Add Doors_Analysis_Apr 2020_v3.xlsx"

SEER = Seasonal Energy Efficiency Ratio; HVAC equipment operating efficiency (Btu/hr-watt)
 = Actual. If unknown, use 13.00⁸⁴⁴

For example, a grocery store installed doors on four open refrigerated cases, which amounted to 12 linear feet of retrofitted display cases, savings the site:

$$\Delta kWh = ((1148 \times 12) / (11.36 \times 1000) \times 8760) + (-2.789 \times 12 \times (1 / 13) \times 1000)$$

$$= 8,049 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((\Delta HG * CL) / (EER * 1000) * CF_{Refrigeration}) + ((MMBtu_{HVAC\ Cool} / Hours_{Cool} * CL * (1 / SEER) * 1000) * CF_{Cool})$$

Where:

Hours_{Cool} = Total combined hours the site is providing cooling
 = 3,329 hours⁸⁴⁵

CF_{Refrigeration} = Summer peak coincidence factor for the refrigerated display case
 = 96.4%

CF_{Cool} = Summer peak coincidence factor for the HVAC cooling system (dependent on building type)

Building Type	CF _{Cool} ⁸⁴⁶	Model Source
Convenience	92.3%	eQuest
Education	96.7%	OpenStudio
Grocery	100.0%	OpenStudio
Health	100.0%	OpenStudio
Hospital	98.6%	OpenStudio
Industrial	44.6%	eQuest
Lodging	97.4%	OpenStudio
Multifamily	100.0%	OpenStudio
Office - Large	98.8%	OpenStudio
Office - Small	100.0%	OpenStudio
Religious	94.3%	eQuest
Restaurant	99.6%	OpenStudio
Retail - Large	87.6%	eQuest
Retail - Small	100.0%	OpenStudio
Warehouse	77.9%	eQuest
Nonresidential Average ⁸⁴⁷	92.3%	N/A

⁸⁴⁴ In light of limited existing market data for the efficiency of commercial air condition equipment in Iowa grocery and convenience stores, SEER assumptions are conservatively sourced from IECC 2012

⁸⁴⁵ The total combined hours in which the site is providing cooling is based on an outdoor air temperature bin analysis, where the site is conditioning cold air at outdoor temperatures of 62.5°F and above. Weather data was sourced from TMY3 data for Des Moines, IA. For more information on the derivation of these hours, please see 'HVAC IE' tab in the "IA TRM_Add Doors_Analysis_Apr 2020_v3.xlsx"

⁸⁴⁶ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁸⁴⁷ For weighting factors, see HVAC variable table in section 3.3.

NATURAL GAS SAVINGS

$$\Delta Therms = MMBtu_{HVAC\ Heat} * CL * (1 / AFUE) * 10$$

Where:

- $\Delta Therms$ = gross customer annual therms savings
- $MMBtu_{HVAC\ Heat}$ = Total heating load decrease on the HVAC equipment per linear foot of display case
= 4.754 MMBtu/ft⁸⁴⁸
- CL = Case Length, refrigerated case length in feet
= Actual
- $AFUE$ = 80%⁸⁴⁹
- 10 = Conversion from MMBtu to therms

PEAK GAS SAVINGS

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

Where:

- $\Delta Therms$ = Therm impact calculated above
- GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁸⁵⁰	Model Source
Convenience	1.6482%	eQuest
Education	1.1480%	OpenStudio
Grocery	1.3083%	OpenStudio
Health	1.0179%	OpenStudio
Hospital	1.5543%	OpenStudio
Industrial	1.4296%	eQuest
Lodging	1.3205%	OpenStudio
Multifamily	1.2268%	OpenStudio
Office - Large	1.3082%	OpenStudio
Office - Small	1.6718%	OpenStudio

⁸⁴⁸ The MMBtu decrease on the HVAC heating equipment is based on an outdoor air temperature bin analysis, the total hours of operation in which the site is providing heat, and the building's overall reduced heating load as a result of the installation of the doors on the open refrigerated display case. The analysis assumes a certain reduction of conditioned air that had to be treated to make up for the air previously cooled by the display case. The reduced heat gain on the refrigerated display case equals the reduced heat loss by the site and a heating load that no longer has to be provided by the HVAC system. Furthermore, the analysis assumes a decrease load on the heating system, at outdoor temperatures below 62.5°F. A 25% disabling factor was also applied to account for some of the cold air pouring out of the display case and subcooling the site's conditioned space, which will not trigger a thermostatic response from the HVAC equipment. For more information on the analysis used to derive the load decrease on the HVAC heating equipment per linear foot of display case, please see the 'HVAC IE' tab in the "IA TRM_Add Doors_Analysis_Apr 2020_v3.xlsx"

⁸⁴⁹ Typical heating system efficiency of 80%, consistent with current heating efficiency assumptions for lighting HVAC interactive effects for commercial fossil fuel-fired systems.

⁸⁵⁰ Calculated as the percentage of total savings in the maximum saving day, from models.

Iowa Energy Efficiency Statewide Technical Reference Manual –3.8.11 Adding Doors to Open Refrigeration Display Cases

Building Type	GCF ⁸⁵⁰	Model Source
Religious	1.1964%	eQuest
Restaurant	1.5262%	OpenStudio
Retail - Large	1.3281%	eQuest
Retail - Small	1.4055%	OpenStudio
Warehouse	1.5677%	eQuest
Nonresidential Average ⁸⁵¹	1.4658%	N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFR-DOOR-V01-210101

SUNSET DATE: 1/1/2026

⁸⁵¹ For weighting factors, see HVAC variable table in section 3.3.

3.8.12. Refrigeration Economizers

DESCRIPTION

This measure applies to commercial walk in refrigeration systems and may include outside air economizers as well as evaporator fan controllers. Economizers save energy by bringing in outside air when weather conditions allow, rather than operating the compressor to satisfy a cooling load. Typically, walk-in refrigeration systems evaporator fans run not only during times the compressor is operating, but also when there is no cooling load to provide air circulation. Evaporator fans can be an inefficient method of providing air circulation since they can be oversized for the sole function of circulation. Therefore, installing an auxiliary circulator fan and using it instead to meet circulation needs can offer additional energy savings. Energy is not only saved from a lower circulation power requirement, but also from the fact that there is less waste heat from the motors that the system would have to subsequently remove. This measure allows for economizer systems with evaporator fan controls plus a circulation fan or without the option of a circulation fan.

This measure was designed to best characterize walk in refrigeration systems with compressors that are less than 8 horsepower in size individually and operate at a temperature setpoint within the range of 15-55 degrees Fahrenheit. Systems not meeting these specifications should be considered on a custom basis.

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. IECC code requires economizers in certain instances and therefore projects relying on code baseline definitions must verify eligibility.

DEFINITION OF EFFICIENT EQUIPMENT

A commissioned economizer system installed on a walk-in refrigeration system.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a walk-in refrigeration system without an economizer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated life of this measure is 15 years.⁸⁵²

DEEMED MEASURE COST

Installation costs can vary considerably depending on system size (larger systems may require multiple economizer units), physical site layouts (locating economizer intakes and ductwork), and controls elected. Therefore, actual site-specific costs should be used as a custom cost input.

LOADSHAPE

Loadshape NRE17 – Refrigeration Economizer

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is dependent on whether the economizer system is installed with an auxiliary circulator fan

⁸⁵² Estimated life from Efficiency Vermont TRM

and controls necessary to turn off evaporator fans when the compressor is not operating.

With Auxiliary Circulator Fan and Controls Installed

$$\Delta kWh = [HP * kWhCond] + [(kWEvap * nFans * DCComp * BF) - kWComp - (kWEcon * DCEcon)] * Hours$$

Without Auxiliary Circulator Fan and Controls Installed

$$\Delta kWh = [HP * kWhCond] - [kWEcon * DCEcon * Hours]$$

Where:

HP = Horsepower of Compressor
= actual installed

kWhCond = Condensing unit savings, per hp. Based on climate zone and compressor type (value from savings table).⁸⁵³

Climate Zone (City based upon)	Hermetic / Semi-Hermetic	Scroll	Discus
Zone 5 (Burlington)	758	665	629
Zone 6 (Mason City)	1149	1009	995
Average/unknown	815	716	667

Hours = Number of annual hours that economizer operates:⁸⁵⁴

Climate Zone (City based upon)	Hours
Zone 5 (Burlington)	1,877
Zone 6 (Mason City)	2,848
Average/unknown	2,020

DCComp = Duty cycle of the compressor
= 50%⁸⁵⁵

kWEvap = Connected load kW of each evaporator fan,
= If known, actual installed. Otherwise assume 0.123 kW⁸⁵⁶

kWCirc = Connected load kW of the circulating fan
= If known, actual installed. Otherwise assume 0.035 kW⁸⁵⁷

nFans = Number of evaporator fans

⁸⁵³ See Iowa Economizer Calc.xls for derivation and details. 5HP compressor size used to develop kWh/Hp value. Assumes no floating head pressure controls and compressor is located outdoors.

⁸⁵⁴ Based on TMY3 data for respective cities. Assumes a cooler setpoint of 38 degrees and economizer deadband setting of 5 degrees (economizer won't begin operation until temperature is 33 degrees or lower).

⁸⁵⁵ A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Travers (35%-65%), Cooltrol (35%-65%), Natural Cool (70%), Pacific Gas & Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor.

⁸⁵⁶ Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts

⁸⁵⁷ Wattage of fan used by Freeaire and Cooltrol. This fan is used to circulate air in the cooler when the evaporator fan is turned off. As such, it is not used when fan control is not present

	= actual number of evaporator fans
DCEcon	= Duty cycle of the economizer fan on days that are cool enough for the economizer to be working = If known, actual installed. Otherwise assume 63% ⁸⁵⁸
BF	= Bonus factor for reduced cooling load attributed to removing waste heat from evaporator fans. Dedicated high-efficiency circulator fans require less power and use high efficiency motors, resulting in less waste heat. = 1.3 ⁸⁵⁹
kWEcon	= Connected load kW of the economizer fan(s) = If known, actual installed. Otherwise assume 0.227 kW. ⁸⁶⁰

For example, adding an outdoor air economizer with an efficient circulator fan and controls in climate zone 5 to a 5 hp walk in refrigeration unit with 3 evaporator fans and a scroll compressor would annually save (assuming other default assumptions):

$$\begin{aligned} \Delta \text{kWh} &= [\text{HP} * \text{kWhCond}] + [((\text{kWEvap} * \text{nFans} * \text{DCComp} * \text{BF}) - \text{kWCirc} - (\text{kWEcon} * \text{DCEcon})) * \text{Hours}] \\ &= [5 * 665] + [((0.123 * 3 * .5 * 1.3) - 0.035 - (0.227 * 0.63)) * 1877] \\ &= 3208.9 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No savings are expected since all savings occur during the winter months.

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ECON-V01-210101

SUNSET DATE: 1/1/2024*

* 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

⁸⁵⁸ Average of two manufacturer estimates of 50% and 75%.

⁸⁵⁹ Bonus factor (1+ 1/3.5) assumes COP of 3.5, based on the average of standard reciprocating and discus compressor efficiencies with a Saturated Suction Temperature of 20°F and a condensing temperature of 90°F

⁸⁶⁰ The 227 watts for an economizer is calculated from the average of three manufacturers: Freeaire (186 Watts), Cooltrol (285 Watts), and Natural Cool (218 Watts).

3.8.13. Auto-Closers for Walk-In Doors

DESCRIPTION

This measure is for installing an auto-closer to the main insulated opaque door(s) of a walk-in cooler or freezer. The auto-closer must firmly close the door when it is within 1 inch of full closure.

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 consists of the installation of an automatic, hydraulic-type door closer on main walk-in cooler or freezer doors. These closers save energy by reducing the infiltration of warm outside air into the refrigeration itself.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a walk-in cooler or freezer without an automatic closure.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 8 years.⁸⁶¹

DEEMED MEASURE COST

The deemed measure cost is \$157.19 for a walk-in cooler or freezer.⁸⁶² This is consistent with the value found in the NW RTF Measure data.

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Savings calculations are based on values from NW Regional Technical Form developed measure “Grocery Store Door Auto Closer”.⁸⁶³

Annual Savings	Refrigerated Space Temperature	kWh
Walk in Cooler	Medium	215
Walk in Freezer	Low	2,730

SUMMER COINCIDENT PEAK DEMAND SAVINGS

⁸⁶¹ DEER 2014 Effective Useful Life

⁸⁶² Southern California Edison “Refrigerated Storage Auto Closer: Work Paper SCE17RN024 Revision 0”, pg 10. November 4, 2016.

⁸⁶³ Based on NW RTF measure (v.2 from 2014) savings, which were based on the consumptions found in lab tests by Emerson Gasket Test Lab, conducted in September 2008. For specific set points & values, please see NW RTF_ComGroceryAutoCloser_v1_2.xlsm.

The measure has deemed kW savings⁸⁶⁴ therefore a coincidence factor does not apply.

Annual Savings	Refrigerated Space Temperature	kW
Walk in Cooler	Medium	0.054
Walk in Freezer	Low	0.680

NATURAL GAS ENERGY 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: NR-RFG-ACWD-V01-220101

SUNSET DATE: 1/1/2027

⁸⁶⁴ Based on NW RTF measure (v.2 from 2014) savings, which were based on the consumptions found in lab tests by Emerson Gasket Test Lab, conducted in September 2008. For specific set points & values, please see NW RTF_ComGroceryAutoCloser_v1_2.xlsm

3.8.14. Refrigeration Tune-Up – Remote Condensing Unit

DESCRIPTION

Refrigeration tune-up (maintenance) includes the professional cleaning of refrigeration system condenser and evaporator tubes, oil level and pressure, compressor and pump checks, pressure control checks, filter inspections, defrost, etc. Follow check list of items for proper operation. This tune-up measure is specific to non-self-contained refrigeration equipment, such as split and rack systems.

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 remote condensing unit refrigeration equipment associated with a commercial enterprise that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The certified technician must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks:

- Clean and inspect condenser and evaporator coils;
- Clean drain pan;
- Inspect/clean fans, screens, grills, filters, and drier cores;
- Check operation and optimize of sub-cooling and superheat temperatures, heat reclaimers, and defrost heaters
- Tighten all line voltage connections;
- Inspect/replace relays and capacitors as needed; and
- Add/remove refrigerant charge as needed.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a commercial remote condensing refrigeration system that has not been inspected or tuned up in more than 12 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 3 years.⁸⁶⁵

DEEMED MEASURE COST

Tune-up costs can vary considerably, particularly if refrigerant leak detection, remediation, and recharge is necessary. Actual invoiced tune-up costs should be used.

LOADSHAPE

Loadshape NRE01 - Non-Residential Refrigeration – Grocery

⁸⁶⁵ The expected measure life is sourced from DEER2014 EUL Table for measures: “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{\left(Capacity * FLH * \left(\frac{1}{EER_{base}} \right) \right)}{1000} * SF$$

Where:

- Capacity = Refrigeration system capacity in Btu/h. See reference table for values based on system compressors. For prescriptive measures the average capacity for each range of size is used.⁸⁶⁶
- EER_{Base} = Efficiency of existing refrigeration system in Btu/watt-hour. Use actual if known. If unknown, default to reference tables for compressor values.
- FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are as follows for the different refrigeration temperature applications.⁸⁶⁷

Refrigeration Application	Full Load Hours
Medium Temperature	3,910
Low Temperature	4,139

- SF = Refrigeration savings factor from tune-up
= 6%⁸⁶⁸

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- kW = gross customer connected load kW savings for the measure (kW)
- FLH = Full load hours. The refrigeration is assumed to be in operation every day of the year, but because of compressor cycling the full load hours are 3910 hours for medium temperature applications and 4139 hours for low temperature applications.⁸⁶⁹
- CF = System Peak Coincidence Factor. Assume non-residential average of 96.4%

⁸⁶⁶ Given this measure characterizes 1.5-10 HP the BTU/hr range is calculated as 1 Btu/Hr to Horsepower = 0.0004. This presenting a valid range of 1- 25199 BTU/hr for Avg. Cap.

⁸⁶⁷ Based on run time estimates from “Performance Standards for Walk-In Refrigerator and Freezer Systems,” AHRTI Report No. 09002-01, by Bryan R. Becker, et al., January 2012, Tables 30-33

⁸⁶⁸ The 6% savings factor represents a mid-point estimate based on the following sources; 7% savings is indicated from Wisconsin’s FOE program. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0 and 5% savings is indicated for combined maintenance/energy service tune-ups from online sources like supermarket green news, chill match, and Verisae.

⁸⁶⁹ Based on run time estimates from “Performance Standards for Walk-In Refrigerator and Freezer Systems,” AHRTI Report No. 09002-01, by Bryan R. Becker, et al., January 2012, Tables 30-33

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES⁸⁷⁰

Baseline and Qualifying EER Values by Capacity, and Temperature Application⁸⁷¹

Low Temperature		
Baseline and Qualifying EER		
Condensing temp 90°F, Evap Temp -25°F		
Capacity Bins in BTU/Hr	HP equivalent ⁸⁷²	Average EERbase
0-4200	1	3.85
4200-8399	2	4.83
8400-12599	3	5.06
12600-16799	4	5.26
16800-20999	5	5.36
21000-25199	6	5.69
25200-29399	7	5.71
29400-33599	8	6.14
33600-37800	9	5.64
37800-42000	10	5.73

Medium Temperature		
Baseline and Qualifying EER		
Condensing temp 90°F, Evap Temp 20°F		
Capacity Bins in BTU/Hr	HP equivalent	Average EERbase
0-7500	1	8.14
7500-14999	2	9.28

⁸⁷⁰ Baseline EERs and Qualifying EERs calculations come from available modeling and installation data provided by Efficiency Vermont referred in the 2014 TRM and supported by referenced document “TRM compressor efficiency analysis.xlsx” for averaging of data for IA TRM.

⁸⁷¹ Supermarket refrigeration systems typically operate at two evaporator temperatures, medium temperature and low temperature. Medium temperature cases vary from 10°F to 35°F with a typical mean evaporating temperature of 20°F. Medium temperature cases are typically used for meats, dairy, beverages and walk-in coolers. Low-temperature cases vary from -15°F to -25°F and are used for frozen foods, ice cream, and walk-in freezers. A typical mean low temperature evaporating temperature is -25°F.

⁸⁷² At low temperatures the standard calculation for Compressor HP vs. Btu/Hr is 4226 Btu/hr per HP. Round numbers to 4200 for ease of binning.

Medium Temperature		
Baseline and Qualifying EER		
Condensing temp 90°F, Evap Temp 20°F		
Capacity Bins in BTU/Hr	HP equivalent	Average EERbase
15000-22499	3	10.64
22500-29999	4	11.18
30000-37499	5	11.12
37500-44999	6	11.74
45000-52499	7	11.68
52500-59999	8	12.54
60000-67499	9	12.46
67500-75000	10	11.44

MEASURE CODE: NR-RFG-TURU-V01-220101

SUNSET DATE: 1/1/2027

3.8.15. Refrigeration Tune-Up – Self-Contained Unit

DESCRIPTION

Refrigeration tune-up (maintenance) includes the professional cleaning of refrigeration system condenser and evaporator tubes, oil level and pressure, compressor and pump checks, pressure control checks, filter inspections, defrost, etc. Follow check list of items for proper operation. This tune-up measure is specific to self-contained refrigeration equipment.

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 self-contained condensing unit refrigeration equipment associated with a commercial enterprise that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The certified technician must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks:

- Clean and inspect condenser and evaporator coils;
- Clean drain pan;
- Inspect/clean fans, screens, grills, filters, and drier cores;
- Check operation and optimize of sub-cooling and superheat temperatures, heat reclaimers, and defrost heaters
- Tighten all line voltage connections;
- Inspect/replace relays and capacitors as needed; and
- Add/remove refrigerant charge as needed.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a commercial self-contained condensing refrigeration system that has not been inspected or tuned up in more than 12 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 3 years.⁸⁷³

DEEMED MEASURE COST

Tune-up costs can vary considerably, particularly if refrigerant leak detection, remediation, and recharge is necessary. Actual invoiced tune-up costs should be used.

LOADSHAPE

Loadshape NRE01 - Non-Residential Refrigeration – Grocery

⁸⁷³ The expected measure life is sourced from DEER2014 EUL Table for measures: “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{kW}{Hp} * Hours * DC * Hp * SF$$

Where:

$$\frac{kW}{Hp} = \frac{(V * A * PF)}{1000 * Hp}$$

- V = Volts
= Actual, if known
- A = Amps
= Actual, if known
- PF = Power factor
= Actual, if known
- Hp = Nominal horsepower of the unit
= Actual

If refrigeration system equipment metrics are unknown, default kW/hp can be sourced from the following tables:⁸⁷⁴

Average Refrigerator Compressor Demand and Consumption per Horsepower (kW/Hp)

Size Tier	kW/Hp	Weighting
¼ hp	1.6503	40%
½ hp	1.3832	40%
¾ hp	1.3800	10%
1 hp	1.4582	10%
Average	1.4972	100%

Average Freezer Compressor Demand and Consumption per Horsepower (kW/Hp)

Size Tier	kW/Hp	Weighting
¼ hp	1.3111	20%
½ hp	1.3984	10%
¾ hp	1.1776	40%
1 hp	1.2637	30%
Average	1.2522	100%

⁸⁷⁴ Source: Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0; March 22, 2010. For the measure "Commercial Refrigeration Tune-up, Self-Contained" pg 4-92. Weights not based on actual market share, but on the number of compressors for which data is available in each category

Hours	= 8,760 hours
DC	=Duty cycle of compressor ⁸⁷⁵ = 62% for refrigerators = 80% for freezers
SF	= Refrigeration savings factor from tune-up = 6% ⁸⁷⁶

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

kW	= gross customer connected load kW savings for the measure (kW)
Hours	= 8760 hours
DC	=Duty cycle of compressor ⁸⁷⁷ = 62% for refrigerators = 80% for freezers
CF	= System Peak Coincidence Factor. Assume non-residential average of 96.4%

NATURAL GAS ENERGY 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: NR-RFG-TUSC-V01-220101

SUNSET DATE: 1/1/2027

⁸⁷⁵ System duty cycle is sourced from, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0; March 22, 2010. For the measure "Commercial Refrigeration Tune-up, Self-Contained" pg 4-92,

⁸⁷⁶ The 6% savings factor represents a mid-point estimate based on the following sources; 7% savings is indicated from Wisconsin's FOE program. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0 and 5% savings is indicated for combined maintenance/energy service tune-ups from online sources like supermarket green news, chill match, and Verisae.

⁸⁷⁷ System duty cycle is sourced from, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0; March 22, 2010. For the measure "Commercial Refrigeration Tune-up, Self-Contained" pg 4-92,

3.8.16. Vending Machine Controllers

DESCRIPTION

This measure relates to the installation of new controls on either a new or existing non-ENERGY STAR refrigerated beverage vending machines. A refrigerated beverage vending machine is a commercial refrigerator that cools bottled and/or canned beverages and dispenses the bottled and/or canned beverages (a beverage in a sealed container) on payment. Controls can significantly reduce the energy consumption of vending machine and refrigeration systems. Qualifying controls must power down these systems during periods of inactivity but, in the case of refrigerated machines, must always maintain a cool product that meets customer expectations.

This measure relates to the installation of a new control on a new or existing unit. This measure should **not** be applied to ENERGY STAR qualified vending machines, as they already have built-in controls.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a control system capable of powering down lighting and refrigeration systems during periods of inactivity.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard non-ENERGY STAR refrigerated beverage vending machine, without a control system capable of powering down lighting and refrigeration systems during periods of inactivity. This includes new or rebuilt, Class A, Class B, Combination A, or Combination B refrigerated vending machines that are not ENERGY STAR certified, but adhere to Federal Energy Conservation Standards.⁸⁷⁸

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 5 years.⁸⁷⁹

DEEMED MEASURE COST

The actual measure installation cost should be used (including material and labor), but the following can be assumed for analysis purposes:

Refrigerated Vending Machine: \$215.50⁸⁸⁰

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

⁸⁷⁸ 10 CFR §431.296 (a) &(b) - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines. (a) is effective for machines manufactured before January 8, 2019. (b) is effective for machines manufactured on or after January 8, 2019.

⁸⁷⁹ The expected measure life is from DEER2014 EUL Table for “Vending Machine Controller”, updated February 5, 2014. This is consistent with the Massachusetts Joint Utilities Measure Life Study, Energy & Resource Solutions, November 2005.

⁸⁸⁰ San Diego Gas & Electric "Work Paper WPSDGENRCS0001 Vending Machine Controller" June 15, 2012. Measure cost + Labor cost.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh_{Lighting} + \Delta kWh_{Ref BMC}$$

$$\Delta kWh_{Lighting} = ((8760 - HOURS_{Occupied}) * W_{Bulb}) / 1000$$

$$\Delta kWh_{Ref BMC} = MDEC * SleepHours / 24 * Days$$

Where:

HOURS_{Occupied} = Assumed hours of occupancy⁸⁸¹

Building Type	HOURS _{Occupied}
Education	1,877
Health	3,806
Hospital	6,520
Industrial	2,850
Lodging	3,061
Multifamily	3,061
Office - Large	2,920
Office - Small	2,920
Religious	2,412
Restaurant	5,443
Retail - Large	4,065
Retail - Small	3,694
Warehouse	2,920
Non-Residential Average	3,065

If Unknown, select the "Non-Residential Average".

W_{Bulb} = Wattage of bulb in Refrigerated Beverage Vending Machine.

= Actual, if unknown use 56.4 W⁸⁸² for fluorescent T8 bulbs⁸⁸³ and 31.6 W⁸⁸⁴ for TLEDs.

⁸⁸¹ Hours of Use per section 3.4 Lighting, weighted per section 3.3 HVAC. The weighting used to average modeled variables into a generic, nonresidential category is based on the number of buildings matching each building type in the 2012 Commercial Buildings Energy Consumption Survey (CBECS) Data for the Midwest Region, West North Central Division, which includes Iowa. Building types that comprise less than 5% of the total population are excluded from the weighted averaging.

⁸⁸² See IL TRM, Section 3.4.5 LED Fixtures for the F32T8 Standard Lamp - 4 foot x 2 bulbs.

⁸⁸³ Per Houghton, D. 1996. "Refrigerated Vending Machines - Overlooked Devices Hold Opportunities for Efficiency, New Services." E Source Tech Update, TU-96-7, the typical backlit display for a refrigerated beverage vending machine consists of two five-foot linear fluorescent lamps." (PGE, SWAP011-01 Vending and Beverage Merchandise Controller measure, MeasureDataSpec file)

⁸⁸⁴ See IL TRM, Section 3.4.5 LED Fixtures for the TLED Lamp x 2 bulbs.

MDEC = Maximum Daily Energy Consumption per Federal regulations⁸⁸⁵.

Class	Vintage	EQN	MDEC (kWh/d)
A	post-2019	$0.052 * V + 2.43$	3.52
B		$0.052 * V + 2.20$	3.29
Combination A		$0.086 * V + 2.66$	4.47
Combination B		$0.111 * V + 2.04$	4.37
A	pre-2019	$0.055 * V + 2.56$	3.72
B		$0.073 * V + 3.16$	4.69

V = Refrigerated Volume.
 = Actual, if unknown use 21 cu. ft. ⁸⁸⁶

SleepHours = Maximum hours of sleep mode per day.
 = 4 hrs ⁸⁸⁷

Days = Operating Days/yr.
 = 365

For example, adding controls to a Class B, post-2019 Vintage, Refrigerated Beverage Vending Machine, with 2 T8 bulbs, located in a Small Office:

$$\Delta kWh = \Delta kWh_{\text{lighting}} + \Delta kWh_{\text{Ref BMC}}$$

$$\Delta kWh_{\text{lighting}} = ((8760 - \text{HOURS}_{\text{Occupied}}) * W_{\text{Bulb}}) / 1000$$

$$= ((8760 - 2920) * 56.4 \text{ W}) / 1000$$

$$= 329 \text{ kWh/yr}$$

$$\Delta kWh_{\text{Ref BMC}} = \text{MDEC} * \text{Usage Reduction Rate} * \text{Days}$$

$$= 3.29 * 4/24 * 365$$

$$= 200 \text{ kWh/yr}$$

$$\Delta kWh = 530 \text{ kWh/yr}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

⁸⁸⁵ 10 CFR 431. Subpart Q §431.296 (a) & (b).

⁸⁸⁶ U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program. (n.d.) "Purchasing Energy-Efficient Refrigerated Beverage Vending Machines." Updated January 2020.

⁸⁸⁷ Itron, Inc. 2005. 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report. Prepared for the California Public Utilities Commission. Pg 3-22.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-RBMC-V01-220101

SUNSET DATE: 1/1/2027

3.8.17. Floating Head Pressure Controls

DESCRIPTION

Installers conventionally design a refrigeration system to condense at a set pressure-temperature setpoint, typically 90 degrees. By installing a “floating head pressure control” condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that as the outdoor temperature drops, the compressor will not have to work as hard to reject heat from the cooler or freezer. This measure is for the application of floating head pressure controls for compressors ≤ 10HP and a condensing temperature set to 70°F. This measure is strictly limited to single compressor systems.

As illustrated in the Algorithms section, impacts for this measure are influenced by compressor horsepower, temperature application (refrigerator or freezer) and whether the system is self-contained or relies on remote condensing. Self-contained units are assumed to reject heat to conditioned or semi-conditioned space, whereas remote condensing units are assumed to reject heat to the outdoor environment.

This measure applies to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is a fully commissioned single-compressor refrigeration system that has been retrofitted with floating head pressure control.

DEFINITION OF BASELINE EQUIPMENT

The baseline is an existing, single-compressor refrigeration system without floating head pressure control.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 15 years.⁸⁸⁸

DEEMED MEASURE COST

Actual equipment and labor costs should be used if available. If actual costs are unknown, the full installed costs, per HP of compressor capacity, can be assumed as:⁸⁸⁹

Unit Type	Temperature Range	
	Low Temperature (Freezer)	Medium Temperature (Refrigerator)
Self-Contained Unit (SCU)	\$404.95/HP	\$442.23/HP
Remote Condensing Unit (RCU)	\$404.95/HP	\$442.23/HP

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

⁸⁸⁸ California DEER 2014 Effective Useful Life (EUL) table. See Reference file “DEER2014 EUL Table Update.xlsx”.

⁸⁸⁹ Costs are based on number of additional valves per condenser motor for different HP ratings and includes installation labor costs. Costs are averaged and shown on a per HP basis. See reference document ComGroceryFHPCSingleCompressor_v2_1.xlsm, worksheet 'CostData&Analysis,' blue highlighted cells. Costs were inflated to 2021\$ from 2012\$ using the US BLS's CPI Inflation Calculator.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = HP * Savings Factor$$

Where:

HP = Actual compressor capacity, in horsepower

Savings Factor = kWh savings per horsepower of compressor rating, based on the following tables⁸⁹⁰:

Zone 5 (Burlington)	Low Temperature (Freezer)	Medium Temperature (Refrigerator)
Condensing Unit	252	131
Remote Condenser	412	386

Zone 6 (Mason City)	Low Temperature (Freezer)	Medium Temperature (Refrigerator)
Condensing Unit	252	131
Remote Condenser	491	460

Average/unknown	Low Temperature (Freezer)	Medium Temperature (Refrigerator)
Condensing Unit	252	131
Remote Condenser	432	405

For example, a medium temperature, remote condensing system with 5 horsepower compressor in Zone 5, would save:

$$\begin{aligned} \Delta kWh &= HP * Savings Factor \\ \Delta kWh &= 5 * 386 \\ &= 1930 kWh \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

⁸⁹⁰ Derived from RTF saving estimates for the NW climate zone and extrapolated to Iowa climate zone by using heating degree-days. RTF, “Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems”, workbook ComGroceryFHPCSingleCompressor_v2_1.xlsm, 2020. See supporting workbook “fhp savings extrapolation iowa.xlsx” for full extrapolation.

ΔkWh = Electric energy savings, calculated above

Hours = Operating hours below the assumed 70°F setpoint, which represents hours where floating head pressure controls will produce savings:⁸⁹¹

Climate Zone (City based upon)	Hours
Zone 5 (Burlington)	6387
Zone 6 (Mason City)	7344
Average/unknown	6661

CF = Summer peak coincidence factor
= 96.4%

For example, a medium temperature, remote condensing system with 5 horsepower compressor in Zone 5, would save:

$$\Delta kW = (1930/6387) * 0.964$$

$$= 0.2913 \text{ kW}$$

NATURAL GAS ENERGY 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: NR-RFG-FHPC-V01-220101

SUNSET DATE: 1/1/2025

⁸⁹¹ Annual average of hours for Iowa weather zones where temperature is below 70°F. This is the assumed condensing temperature that is set for the floating head pressure control. Hours are deemed from TMY3 weather data. See “fhp savings extrapolation iowa.xlsx” for further details.

3.9. Compressed Air

3.9.1. Air Compressor with Integrated VSD

DESCRIPTION

This measure applies to the installation of an air compressor with an integrated variable frequency drive, load/no load controls, or variable displacement controls. Baseline compressors choke off the inlet air to modulate the compressor output, which is not an efficient response operation. Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are sourced from DOE data in which variable speed compressor are compared to modulating compressors. This measure applies only to an individual compressor ≤ 200 hp. Only one compressor per compressed air distribution system is eligible.

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

The high efficiency equipment is a compressor ≤ 200 hp with variable speed controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is either an oil-flooded compressor ≤ 200 hp with inlet modulating with blowdown or load/no-load controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 13 years.⁸⁹²

DEEMED MEASURE COST

$$\text{Incremental cost} = (\$127 \times \text{hp}_{\text{compressor}}) + \$1,446.^{893}$$

Where:

\$127 and \$1,446 = compressor motor nominal hp to incremental cost conversion factor and offset

$\text{hp}_{\text{compressor}}$ = compressor motor nominal hp

LOADSHAPE

NRE13 – Indust. 1-shift (8/5)

NRE14 – Indust. 2-shift (16/5)

NRE15 – Indust. 3-shift (24/5)

NRE16 – Indust. 4-shift (24/7)

⁸⁹² "Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial and Industrial Equipment: Air Compressors", U.S. Department of Energy, December 2016 (pg. 8-12)

⁸⁹³ Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost. Values as derived from a survey conducted by several vendors to determine equipment cost, as sourced from the Efficiency Vermont TRM, December 2018.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = 0.9 * hp_{compressor} * Hours * (CF_b - CF_e)$$

Where:

- ΔkWh = gross customer annual kWh savings
- 0.9^{894} = compressor motor nominal hp to full load kW conversion factor
- $hp_{compressor}$ = compressor motor nominal hp
- Hours = compressor total hours of operation depending on shift, listed in the table below

Shift	Hours
Single shift (8/5)	1,976 hours (7 AM – 3 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
2-shift (16/5)	3,952 hours (7 AM – 11 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
3-shift (24/5)	5,928 hours (24 hours per day, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
4-shift (24/7)	8,320 hours (24 hours per day, 7 days a week, minus three-weekday holidays and 10 days of scheduled down time)
Unknown / Weighted average ⁸⁹⁵	5,680 hours

CF_b = baseline compressor factor

Baseline Compressor	Compressor Factor (≤ 40 hp) ⁸⁹⁶	Compressor Factor (50 - 200 hp) ⁸⁹⁷
Modulating w/ Blowdown	0.890	0.863
Load/No Load w/ 1 Gallon/CFM	0.909	0.887

⁸⁹⁴ Conversion factor based on a review of CAGI data sheets from 200 compressors. The survey and the resulting factor are sourced from the Illinois TRM, version 8.0, October 2019 analysis file “IL TRM VSD Air Compressor – Supporting Information.xls” (4.7.1 VSD Air Compressor).

⁸⁹⁵ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

⁸⁹⁶ Compressor factors for this size range were developed using U.S. Department of Energy part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM. (The “variable speed drive” compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD).

⁸⁹⁷ Compressor factors for this size range were developed using U.S. Department of Energy part-load data for different compressor control types as well as load profiles from 45 compressors and 20 facilities. This data comes from the ComEd Custom and Industrial Systems program. The compressors were filtered to reflect only rotary screw compressors, between 50 and 200 hp, and operating a minimum of 4 hour per day. Additionally, compressors with clear and consistent baseload profiles were excluded from this analysis. The evaluation and analysis are sourced from the Illinois TRM, version 8.0, October 2019 analysis file “IL TRM VSD Air Compressor – Supporting Information.xls” (4.7.1 VSD Air Compressor).

Baseline Compressor	Compressor Factor (≤ 40 hp) ⁸⁹⁶	Compressor Factor (50 - 200 hp) ⁸⁹⁷
Load/No Load w/ 3 Gallon/CFM	0.831	0.811
Load/No Load w/ 5 Gallon/CFM	0.806	0.786

CF_e = efficient compressor factor
 = 0.705 for compressor ≤ 40 hp
 = 0.658 for compressors 50 – 200 hp

For example, a 20-horsepower compressor with inlet modulating with blowdown controls is integrated with a VSD, operating a single-shift facility would save:

$$\Delta kWh = 0.9 \times 20 \times 1,976 \times (0.890 - 0.705)$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ⁸⁹⁸	80%

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: NR-MSV-VSDA-V01-210101

SUNSET DATE: 1/1/2026

⁸⁹⁸ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

3.9.2. High Efficiency Air Nozzles

DESCRIPTION

This measure is for the replacement of standard air nozzles with high efficiency air nozzles used in a compressed air system. High efficiency air nozzles reduce the amount of air required to blow off parts or for drying; pulling in free air to accomplish tasks with significantly less compressed air. These nozzles often replace simple copper tubes in a production application or on handheld guns and have added benefits of noise reduction and improved safety in systems with greater than 30 psig.

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 high efficiency air nozzle must replace continuous open blow-offs and meet the following SCFM ratings (or less) at an operating pressure of 80 psig for the following orifice diameters:

Orifice Diameter	SCFM
1/8"	11
1/4"	29
5/16"	56
1/2"	140

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard air nozzle, such as an open copper tube or an inefficient air gun.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 15 years.⁸⁹⁹

DEEMED MEASURE COST

The incremental cost, depending on the orifice diameter, is as follows:

Orifice Diameter	Incremental Cost
1/8"	\$42
1/4"	\$57
5/16"	\$87
1/2"	\$121

LOADSHAPE

- NRE13 – Indust. 1-shift (8/5)
- NRE14 – Indust. 2-shift (16/5)
- NRE15 – Indust. 3-shift (24/5)
- NRE16 – Indust. 4-shift (24/7)

⁸⁹⁹ PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = SCFM_{Baseline} * SCFM_{Efficient} * \%Use * kW/CFM_{Saved} * Hours$$

Where:

ΔkWh = gross customer annual kWh savings

$SCFM_{Baseline}$ = Air flow through baseline nozzle. Use actual rated flow at 80 psi if known. If unknown, please see table below, which includes air flow in SCFM by orifice diameter:⁹⁰⁰

Baseline Orifice Diameter	$SCFM_{Baseline}$
1/8"	21
1/4"	58
5/16"	113
1/2"	280

$SCFM_{Efficient}$ = Air flow through the efficient nozzle. Use actual rated flow rate at 80 psi if known. If unknown, please see table below which includes air flow in SCFM by orifice diameter:⁹⁰¹

Efficient Orifice Diameter	$SCFM_{Efficient}$
1/8"	10.5
1/4"	29.0
5/16"	56.5
1/2"	140

$\%Use$ = Percent of the compressor total operating hours that the nozzle is in use
= 5%⁹⁰²

kW/CFM_{Saved} = System power reduction per reduced air demand (kW/CFM), depending on the type of air compressor listed in the table below:⁹⁰³

Air Compressor Type	kW/CFM_{Saved}
Reciprocating – On/Off Control	0.184
Reciprocating – Load/Unload	0.136
Screw – Load/Unload	0.152

⁹⁰⁰ Review of manufacturer’s information and data as sourced from “Technical Reference Manual (TRM) for Ohio, Senate Bill 221: Energy Efficiency and Conservation Program”, October 15, 2009 (pg. 170-171)

⁹⁰¹ The default efficient air flow is based on an assumed 50% reduction factor on the default baseline air flow, as sourced as a conservative estimate based on average values provided by the Compressed Air Challenge Training Program, Machinery’s Handbook 25th Edition and manufacturer’s catalogue

⁹⁰² The 5 % percent use of the total compressor operating hours is based on an estimate that nozzles are used, on average, for 3 seconds per minute of operation. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long-term open blow situation. An assumption of 3 seconds of blow-off per minute of compressor run time is used, assuming a weighting of 50% handheld air guns and 50% stationary air nozzles.

⁹⁰³ Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. The calculation and analysis are sourced from the Illinois TRM, version 8.0, October 2019 analysis file “Industrial System Standard Deemed Savings Analysis.xls” (4.7.4 Efficient Compressed Air Nozzles).

Air Compressor Type	kW/CFM _{Saved}
Screw – Inlet Modulation	0.055
Screw – Inlet Modulation w/ Unloading	0.055
Screw – Variable Displacement	0.153
Screw - VFD	0.178
Unknown / Weighted average ⁹⁰⁴	0.107

Hours = Compressor total hours of operation. Use actual if known, otherwise, assume values depending on shift, listed in the table below:

Shift	Hours
Single shift (8/5)	1,976 hours (7 AM – 3 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
2-shift (16/5)	3,952 hours (7 AM – 11 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
3-shift (24/5)	5,928 hours (24 hours per day, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
4-shift (24/7)	8,320 hours (24 hours per day, 7 days a week, minus three-weekday holidays and 10 days of scheduled down time)
Unknown / Weighted average ⁹⁰⁵	5,680 hours

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ⁹⁰⁶	80%

NATURAL GAS SAVINGS

⁹⁰⁴ If compressor control type is unknown, a weighted average based on market share can be used as a default. The weighted average is based on the following market share estimates: 40% reciprocating compressor with load/unload controls; 40% modulation compressor with unloading controls; and 20% variable displacement control compressors

⁹⁰⁵ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

⁹⁰⁶ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MS-ACNZ-V01-210101

SUNSET DATE: 1/1/2026

3.9.3. No Loss Condensate Drains

DESCRIPTION

When air is compressed, water in the form of condensation squeezes out of the compressed air and collects in piping and storage tanks. The water must be drained so as not to interfere with the flow of compressed air, as well as to reduce the potential for corrosion to the piping or tank. Many drains are controlled by a timer and open an orifice for a programmed set amount of time, regardless of the level of the condensate. As a result, compressed air is allowed to escape after the condensate has drained. Timed drains typically continue to operate even when the compressor is down, effectively bleeding off useful stored air that must be remade when the compressor is restarted. No loss condensate drains are controlled by a sensor and only open and close when there is a need to drain condensate, effectively closing before compressed air can escape.

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 high efficiency equipment is a no loss condensate drain that is controlled by a sensor and only opens when there is a need to drain condensate, closing before any compressed air is vented.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard condensate drain (open valve, timer, or both) that operates according to a preset schedule regardless of the amount or presence of condensate.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 13 years.⁹⁰⁷

DEEMED MEASURE COST

The average equipment cost per drain is \$194 with an installation labor cost of \$50 for a total incremental cost of \$244 per drain.⁹⁰⁸

LOADSHAPE

NRE03 – Industrial Motor

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = CFM_{reduced} * kW/CFM_{saved} * Hours$$

⁹⁰⁷ “Measure Life Study”, prepared for the Massachusetts Joint Utilities, Energy & Resources Solutions, 2005. Value is based on C&I compressor retrofit effective useful lives.

⁹⁰⁸ Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data. The cost analysis and product review is sourced from the Illinois TRM, version 8.0, October 2019 analysis file “CAS Cost Data.xls” (4.7.3 Compressed Air No-Loss Condensate Drains)

Where:

ΔkWh = gross customer annual kWh savings

$CFM_{reduced}$ = Reduced air consumption per drain
 = 3 CFM⁹⁰⁹

kW/CFM_{saved} = System power reduction per reduced air demand (kW/CFM), depending on the type of air compressor listed in the table below:⁹¹⁰

Air Compressor Type	kW/CFM_{saved}
Reciprocating – On/Off Control	0.184
Reciprocating – Load/Unload	0.136
Screw – Load/Unload	0.152
Screw – Inlet Modulation	0.055
Screw – Inlet Modulation w/ Unloading	0.055
Screw – Variable Displacement	0.153
Screw - VFD	0.178
Unknown / Weighted average ⁹¹¹	0.107

Hours = Compressed air system pressurized hours
 = 6,136 hours⁹¹²

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure
 = 95%

NATURAL GAS SAVINGS

N/A

PEAK GAS SAVINGS

N/A

⁹⁰⁹ Reduced CFM consumption is based on a timer drain opening 10 seconds every 300 seconds as the baseline. This value is sourced from the Illinois TRM, version 8.0, October 2019 analysis file “Industrial System Standard Deemed Savings Analysis.xls” (4.7.3 Compressed Air No-Loss Condensate Drains).

⁹¹⁰ Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. The calculation and analysis are sourced from the Illinois TRM, version 8.0, October 2019 analysis file “Industrial System Standard Deemed Savings Analysis.xls” (4.7.3 Compressed Air No-Loss Condensate Drains).

⁹¹¹ If compressor control type is unknown, a weighted average based on market share can be used as a default. The weighted average is based on the following market share estimates: 40% reciprocating compressor with load/unload controls; 40% modulation compressor with unloading controls; and 20% variable displacement control compressors

⁹¹² “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (pg. 19). The hours are based on an average of 118 hours per week.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MS-C-NLCD-V01-210101

SUNSET DATE: 1/1/2026

3.9.4. Low Pressure Drop Filters

DESCRIPTION

Low pressure drop filters remove solids and aerosols from compressed air systems with a longer life and lower pressure drop than standard coalescing filters, resulting in the ability to lower a compressed air systems pressure setpoints. This reduces the compressor work required resulting in energy savings.

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 a low pressure drop filter with pressure drop not exceeding 1 psid when new and 3 psid at element change.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard coalescing filter with a pressure drop of 3 psid when new and 5 psid or more at element change

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 10 years ⁹¹³

DEEMED MEASURE COST

The incremental cost for this measure is estimated to be \$1,000 per filter. ⁹¹⁴

LOADSHAPE

NRE03 – Industrial Motor

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kW_{typical} * \Delta P * SF * Hours * \frac{HP_{actual}}{HP_{typical}}$$

Where:

$kW_{typical}$ = Adjusted compressor power (kW) based on typical compressor loading and operating profile. Use actual compressor control type if known:

⁹¹³ Based on survey of manufacturer claims (Zeks, Van Air, Quincy).

⁹¹⁴ Based on incremental cost research found in 'CAS Cost Data LPDF. xlsx'.

Control Type	kW _{typical} ⁹¹⁵
Reciprocating - On/off Control	70.2
Reciprocating - Load/Unload	74.8
Screw - Load/Unload	82.3
Screw - Inlet Modulation	82.5
Screw - Inlet Modulation w/ Unloading	82.5
Screw - Variable Displacement	73.2
Screw - VFD	70.8
Unknown / Weighted average ⁹¹⁶	77.6

ΔP = Reduction in pressure differential across the filter (psi)
 =2 psi⁹¹⁷

SF =1% reduction in power per 2 psi reduction in system pressure is equal to 0.5% reduction per 1 psi, or a Savings Factor of 0.005⁹¹⁸

Hours = Compressor hours of operation below depending on shift

Shift	Hours
Single shift (8/5)	1976 hours 7 AM – 3 PM, weekdays, minus some holidays and scheduled down time
2-shift (16/5)	3952 hours 7AM – 11 PM, weekdays, minus some holidays and scheduled down time
3-shift (24/5)	5928 hours 24 hours per day, weekdays, minus some holidays and scheduled down time
4-shift (24/7)	8320 hours 24 hours per day, 7 days a week minus some holidays and scheduled down time

HP_{typical} = Nominal HP for typical compressor
 = 100 HP⁹¹⁹

HP_{Actual} = Total HP of actual compressors distributing air through filter. This should include the total horsepower of the compressors that normally run through the filter, but not backup compressors.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer peak coincidence factor for this measure

⁹¹⁵ See “Industrial System Standard Deemed Saving Analysis.xls”.

⁹¹⁶ If compressor control type is unknown, a weighted average based on market share can be used as a default. The weighted average is based on the following market share estimates: 40% reciprocating compressor with load/unload controls; 40% modulation compressor with unloading controls; and 20% variable displacement control compressors

⁹¹⁷ Assumed pressure will be reduced from a roughly 3 psi pressure drop through a filter to less than 1 psi, for a 2 psi savings

⁹¹⁸ “Optimizing Pneumatic Systems for Extra Savings,” Compressed Air Best Practices, DOE Compressed Air Challenge, 2010.

⁹¹⁹ See “Industrial System Standard Deemed Saving Analysis.xls”.

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ⁹²⁰	80%

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: NR-MS-C-LPDF-V01-220101

SUNSET DATE: 1/1/2026

⁹²⁰ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

3.9.5. Storage Receiver Tank

DESCRIPTION

Using an air receiver or storage tank will buffer the air demands of the system on the compressor, thus eliminating short cycling. Although a load/no load compressor unloads in response to lowered demand, it does so over a period of time to prevent lubrication oil from foaming. Therefore, reducing the number of cycles reduces the number of transition times from load to no load and saves energy.

To qualify for this measure an existing load/no load compressor with a 1 gal/cfm storage ratio or a modulating w/ blowdown compressor must be replaced with a load/no load compressor with an improved storage capacity and ratio.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is an oil-flooded load/no load compressor with an improved storage capacity and ratio compared to the existing system. The cfm should reflect the rated capacity (in cfm) of all active compressors. If that value cannot be determined, compressor power can be converted to capacity using the rule-of-thumb 4.5 cfm/hp.⁹²¹

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an oil-flooded load/no load compressor with a 1 gal/cfm storage ratio or a modulating w/ blowdown compressor.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is 10 years⁹²²

DEEMED MEASURE COST

$$\text{Incremental cost (\$)} = 4.67 * (\text{TANK}_E - \text{TANK}_B)^{923}$$

Where:

4.67 = air receiver tank size, in gallons, to equipment cost conversion factor

TANK_E = efficient tank size (gallons)

TANK_B = baseline tank size (gallons)

LOADSHAPE

NRE03 – Industrial Motor

⁹²¹ The 4.5 cfm/hp rule of thumb is based on a rotary screw compressor delivering 4 to 5 cfm per 1 hp, “Relationship Between Pressure and Flow”, Compressed Air System Best Practices, Industrial Utility Efficiency.

⁹²² 2018 Vermont PUC: Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions

⁹²³ 2018 Vermont PUC: Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$DkWh = 0.9 * HP_{compressor} * HOURS * (CF_b - CF_e)$$

Where:

0.9⁹²⁴ = compressor motor nominal HP to full load kW conversion factor

HP_{compressor} = compressor motor nominal HP

= Actual

HOURS = compressor total hours of operation below depending on shift

Shift	Hours
Single shift (8/5)	1,976 hours (7 AM – 3 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
2-shift (16/5)	3,952 hours (7 AM – 11 PM, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
3-shift (24/5)	5,928 hours (24 hours per day, weekdays, minus three-weekday holidays and 10 days of scheduled down time)
4-shift (24/7)	8,320 hours (24 hours per day, 7 days a week, minus three-weekday holidays and 10 days of scheduled down time)
Unknown / Weighted average ⁹²⁵	5,680 hours

CF_b = baseline compressor factor⁹²⁶

= See table below for baseline compressor factor. If compressor type is unknown, default to a load/no load compressor with 1 gallon/cfm for the appropriate-sized compressor.

⁹²⁴ Conversion factor based on Survey of CAGI data sheets from 200 compressors. See “IL TRM VSD Air Compressor – Supporting Information.xls” for more information.

⁹²⁵ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

⁹²⁶ Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM.

Baseline Compressor	Compressor Factor (≤ 40 hp) ⁹²⁷	Compressor Factor (50 – 200 hp) ⁹²⁸
Modulating w/ Blowdown	0.890	0.863
Load/No Load w/ 1 Gallon/CFM	0.909	0.887
Load/No Load w/ 3 Gallon/CFM	0.831	0.811
Load/No Load w/ 4 Gallon/CFM	0.812	0.792
Load/No Load w/ 5 Gallon/CFM	0.806	0.786

CF_e = efficient compressor factor

= See table above for load/no load compressors with the adequate storage capacity installed. If unknown, default to load/no load compressors w/ 4 gallons/cfm.

For example, a 2-shift facility with a 100-hp modulating (with blowdown) adds a 2,000-gallon receiver to their compressed air system. This improvement brings the system storage over 4 gallons per cfm.

$$\begin{aligned} \text{Capacity Check:} &= 2,000 \text{ gallons} / (100 \text{ hp} * 4.5 \text{ cfm/hp}) \\ &= 4.4 \text{ gallons per cfm} \end{aligned}$$

$$\begin{aligned} \Delta \text{kWh} &= 0.9 * 100 * 3,952 * (0.863 - 0.792) \\ &= 25,253 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$DkW = \frac{DkWh}{HOURS} * CF$$

Where:

CF = Summer peak coincidence factor for this measure

Shift	Coincidence Factor
Single shift (8/5)	0%
2-shift (16/5)	95%
3-shift (24/5)	95%
4-shift (24/7)	95%
Unknown / Weighted average ⁹²⁹	80%

⁹²⁷ Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM. See “IL TRM VSD Air Compressor – Supporting Information.xls” for more information.

⁹²⁸ Compressor factors for this size range were developed using DOE part-load data for different compressor control types as well as load profiles from 45 compressors and 20 facilities. This data comes from ComEd Custom and Industrial Systems programs. The compressors were filtered to reflect only rotary screw compressors, between 50 and 200 hp, and operating a minimum of 4 hour per day. Additionally, compressors with clear and consistent baseload profiles were excluded from this analysis. See “IL TRM VSD Air Compressor – Supporting Information.xls” for more information.

⁹²⁹ Weighting of 16.1% single shift, 23.2% two-shift, 25.3% three-shift, and 35.4% four-shift as sourced from, “Evaluation of the Compressed Air Challenge Training Program”, U.S. Department of Energy, March 2004 (section 2.1.5 Facility Operating Schedules)

For example, a 2-shift facility with a 100-hp VSD modulating (with blowdown) compressor adds a 2,000-gallon receiver to their compressed air system. This improvement brings the system storage over 4 gallons per cfm.

$$\begin{aligned} \Delta kW &= 25,253 / 3,952 * 0.95 \\ &= 6.1 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY 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: NR-MS-C-SRT-V01-220101

SUNSET DATE: 1/1/2026