

Iowa Energy Efficiency Statewide Technical Reference Manual

Volume 3: Nonresidential Measures

Final: August 1, 2016

Effective: January 1, 2017

[INTENTIONALLY LEFT BLANK]

Table of Contents

Volume 1: Overview and User Guide

Volume 2: Residential Measures

Volume 3: Nonresidential Measures..... 6

3.1 Agricultural Equipment..... 6

- 3.1.1 Circulation Fans6
- 3.1.2 Ventilation Fans9
- 3.1.3 High Volume Low Speed Fans.....12
- 3.1.4 Temperature Based On/Off Ventilation Controller15
- 3.1.5 Automatic Milker Take Off17
- 3.1.6 Dairy Scroll Compressor19
- 3.1.7 Heat Lamp.....22
- 3.1.8 Heat Reclaimer24
- 3.1.9 Heat Mat.....27
- 3.1.10 Grain Dryer31
- 3.1.11 Live Stock Waterer33
- 3.1.12 Low Pressure Irrigation.....35
- 3.1.13 Variable Speed Frequency Drive for Dairy Vacuum Pump and Milking Machine37
- 3.1.14 Dairy Plate Cooler39

3.2 Hot Water..... 42

- 3.2.1 Low Flow Faucet Aerators42
- 3.2.2 Low Flow Showerheads51
- 3.2.3 Gas Hot Water Heater57
- 3.2.4 Controls for Central Domestic Hot Water62
- 3.2.5 Pool Covers64
- 3.2.6 Drainwater Heat Recovery67

3.3 Heating, Ventilation and Air Conditioning (HVAC) 72

- 3.3.1 Boiler73
- 3.3.2 Furnace76
- 3.3.3 Furnace Blower Motor.....79
- 3.3.4 Heat Pump Systems.....82
- 3.3.5 Geothermal Source Heat Pump.....87
- 3.3.6 Single-Package and Split System Unitary Air Conditioners.....91

Iowa Energy Efficiency Statewide Technical Reference Manual – Table of Contents

3.3.7	Electric Chiller	96
3.3.8	Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP).....	101
3.3.9	Guest Room Energy Management (PTAC).....	107
3.3.10	Boiler Tune-up	110
3.3.11	Furnace Tune-Up	113
3.3.12	Small Commercial Programmable Thermostats	116
3.3.13	Variable Frequency Drives for HVAC Pumps.....	119
3.3.14	Variable Frequency Drives for HVAC Supply and Return Fans.....	122
3.3.15	Duct Insulation	127
3.3.16	Duct Repair and Sealing	132
3.3.17	Chiller Pipe Insulation	139
3.3.18	Hydronic Heating Pipe Insulation	143
3.3.19	Shut Off Damper for Space Heating Boilers or Furnaces	148
3.3.20	Room Air Conditioner	151
3.3.21	Room Air Conditioner Recycling	155
3.4	Lighting.....	158
3.4.1	Compact Fluorescent Lamp - Standard	159
3.4.2	Compact Fluorescent Lamp - Specialty.....	164
3.4.3	LED Lamp Standard.....	171
3.4.4	LED Lamp Specialty.....	177
3.4.5	LED Fixtures	183
3.4.6	T5 HO Fixtures and Lamp/Ballast Systems	190
3.4.7	High Performance and Reduced Wattage T8 Fixtures and Lamps	194
3.4.8	Metal Halide	199
3.4.9	Commercial LED Exit Sign	203
3.4.10	LED Street Lighting.....	207
3.4.11	LED Traffic and Pedestrian Signals.....	210
3.4.12	Occupancy Sensor.....	213
3.4.13	Daylighting Control	217
3.4.14	Multi-Level Lighting Switch.....	220
3.5	Miscellaneous.....	223
3.5.1	Variable Frequency Drives for Process	223
3.5.2	Clothes Washer.....	225
3.5.3	Motors	231

3.6 Food Service	235
3.6.1 Dishwasher	235
3.6.2 Commercial Solid and Glass Door Refrigerators & Freezers.....	244
3.6.3 Pre-Rinse Spray Valve	248
3.6.4 Infrared Upright Broiler	252
3.6.5 Infrared Salamander Broiler	255
3.6.6 Infrared Charbroiler	258
3.6.7 Convection Oven	261
3.6.8 Conveyor Oven	266
3.6.9 Infrared Rotisserie Oven.....	270
3.6.10 Commercial Steam Cooker	273
3.6.11 Fryer.....	279
3.6.12 Griddle	284
3.7 Shell.....	289
3.7.1 Infiltration Control.....	289
3.7.2 Foundation Wall Insulation	296
3.7.3 Roof Insulation.....	301
3.7.4 Wall Insulation.....	306
3.7.5 Efficient Windows.....	311
3.7.6 Insulated Doors.....	316
3.8 Refrigeration	321
3.8.1 LED Refrigerator Case Light Occupancy Sensor	321
3.8.2 Door Heater Controls for Cooler or Freezer	324
3.8.3 Electronically Commutated Motors (ECM) for Walk-in and Display Case Coolers / Freezers	327
3.8.4 Night Covers for Open Refrigerated Display Cases.....	330
3.8.5 Refrigerated Beverage Vending Machine.....	333
3.8.6 Refrigerator and Freezer Recycling	336
3.8.7 Scroll Refrigeration Compressor.....	344
3.8.8 Strip Curtain for Walk-in Coolers and Freezers	348
3.8.9 Ice Maker	351

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 (CMF/Watt) at (0.05 SP)
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 16 years³.

DEEMED MEASURE COST

The incremental capital cost for all fan sizes is actual cost. If actual costs are not available, use \$150.⁴

LOADSHAPE

¹ Cubic Feet per Minute

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

³ Average motor life: 35,000 hours divided by annual run hours, taken to be the default average of 2,099 (see description of default on following pages). Rounded down to nearest whole year. Motor life source: US DOE Advanced Manufacturing Office. Motor Systems Tip Sheet #3.

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

Loadshape NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

Watts_base⁵ = Demand (W) of baseline fan

Diameter of Fan (inches)	Watts_base (0.05 SP)
12-23	366
24-35	615
36-47	810
48+	1358

Watts_ee⁶ = Demand (W) of efficient fan

Diameter of Fan (inches)	Watts_ee (0.05 SP)
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 table⁷ can be used to establish operating hours by facility type (hog or dairy). For dairy facilities the typical temperature setpoint can be assumed to be 70°F, and for hog facilities it can be assumed to be 60°F, as these are the recommended temperatures above which comfort cooling should be provided for livestock⁸.

Facility Type	Annual Hours of Operation
Hog	3597
Dairy	2099

Nfans = Number of circulation fans
= Actual

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_base - Watts_ee}{1000} * CF * Nfans$$

⁵ BESS fan database downloaded on 7/1/2015. Average watts from models below standard. AgCirculation Fans.xls

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

⁷ Based on TMY3 data for Des Moines.

⁸ Dairy Farm Energy Management Guide, Southern California Edison February 2004.

Where:

CF = Summer Peak Coincidence Factor
= 100%⁹

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-V01-170101

SUNSET DATE: 1/1/2021

⁹ 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 Labs¹⁰ with fan diameters above 14 inches that meet program minimum efficiency requirements.

Diameter of Fan (inches)	IPL Minimum Efficiency (CMF/Watt) at (0.05 SP ¹¹)
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 16 years¹².

DEEMED MEASURE COST

The incremental capital cost for all fan sizes is actual cost. If actual cost not available, use \$150¹³.

LOADSHAPE

Loadshape NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

¹⁰ University of Illinois, Department of Agricultural and Biological Engineering. <http://bess.illinois.edu/>

¹¹ Static Pressure.

¹² Average motor life: 35,000 hours divided by annual run hours, taken to be the default average of 2,099 (see description of default on following pages). Rounded down to nearest whole year. Motor life source US DOE Advanced Manufacturing Office. Motor Systems Tip Sheet #3.

¹³ Act on Energy Commercial Technical Reference Manual No. 2010-4.

ELECTRIC ENERGY SAVINGS

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

Where:

Watts_base¹⁴ = 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_ee¹⁵ = 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 and dairy facilities, based on typical control schedules¹⁶.

Facility Type	Annual EFLH
Hog	4923
Dairy	4205

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%¹⁷

NATURAL GAS ENERGY SAVINGS

¹⁴ BESS fan database downloaded on 7/1/2015. Average watts from models below standard. AgVentilationFans.xls

¹⁵ BESS fan database downloaded on 7/1/2015. Average watts from models above standard. AgVentilationFans.xls

¹⁶ See "Ventilation Op Hours.xlsx" workbook for a complete description and derivation of default operating hours. EFLH based on TMY3 data for Des Moines.

¹⁷ Industrial Ventilation CF from eQuest.

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-V01-170101

SUNSET DATE: 1/1/2021

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 16 years¹⁸.

MEASURE COST

As a retrofit measure, the actual installation cost should be used for screening and reporting purposes. For a new construction measure, the incremental measure costs are as follows¹⁹:

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

LOADSHAPE

Loadshape– NREV06-Industrial Ventilation

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

¹⁸ Average motor life: 35,000 hours divided by annual run hours, taken to be the default average of 2,099 (see description of default on following pages). Rounded down to nearest whole year. Motor life source US DOE Advanced Manufacturing Office. Motor Systems Tip Sheet #3.

¹⁹ 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.

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

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 savings

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 table²⁰ can be used to establish operating hours. For dairy facilities the typical temperature setpoint can be assumed to be 70°F, and for hog facilities it can be assumed to be 60°F, as these are the recommended temperatures above which comfort cooling should be provided for livestock.²¹

Facility Type	Annual Hours of Operation
Hog	3597
Dairy	2099

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%²²

NATURAL GAS ENERGY SAVINGS

²⁰ Based on TMY3 data for Des Moines.

²¹ Dairy Farm Energy Management Guide, Southern California Edison February 2004.

²² Industrial Ventilation CF from eQuest.

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-V01-170101

SUNSET DATE: 1/1/2021 ‘

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 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 7 years²³.

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

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

Where:

²³ Average motor life 35,000 hours as estimated by US DOE Advanced Manufacturing Office. Motor Systems Tip Sheet #3 divided by run hours.

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

Watts_fan = Total wattage of controlled fans
 = Actual - If unknown, the following table can be used to estimate:²⁴:

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 controller
 = 1384 hours for hog facilities or 624 hours for dairy facilities²⁵

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A - Assume fans will be running 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-V01-170101

SUNSET DATE: 1/1/2021

²⁴ BESS fan database downloaded on 7/1/2015. Average watts from models considered baseline. AgVentilationFans.xls

²⁵ Refer to "Ventilation Op Hours.xlsx" workbook for a complete derivation.

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 1995²⁶, 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 improvements.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a milker takeoff is 15²⁷ years.

DEEMED MEASURE COST

Retrofit measure, actual costs will be used.

LOADSHAPE

Loadshape NRE11 – Nonresidential Agriculture

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS ALGORITHM:

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

Where:

- kWh/Cow = 5028
- Nmilings = Number of milkings per day
= Actual, if unknown use 2²⁹
- Ncows = Number of milking cows per farm
= Actual, if unknown use 90³⁰

²⁶ 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.

²⁷ Value based on engineering judgment.

²⁸ 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.

²⁹ Default value based on engineering judgment, Alliant's Global Energy Partners impact calculations in DSM Tracking, 2006.

³⁰ 2007 AG Census in IA. Average number of cows per farm = 215,391/2,390 = 90, p. 393:

SUMMER COINCIDENT PEAK DEMAND SAVINGS:

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

Where:

FLH = Full Load Hours
= 3784³¹

CF = Coincidence Factor
= 0.793³²

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-V01-170101

SUNSET DATE: 1/1/2021

http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf

³¹ Assumes average number of milkings per day is 2.8, average hours per milking is 3.7 hours and milking occurs 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

³² 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 years³³.

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

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

Where:

EER_{base} = Cooling efficiency of existing compressor in Btu/watt-hour
 = Actual, if unknown use values from table below³⁴

EER_{ee} = Cooling efficiency of efficient scroll compressor in Btu/watt-hour
 = Actual, if unknown use values from table below³⁵

³³ 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)

³⁴ 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.

³⁵ Efficiency Vermont TRM User Manual No. 2014-87 and spreadsheet compressor efficiency analysis EVT Refrigeration

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
= 6³⁶

Days_{Syr} = Number of days per year
= 365.25

Specific_{Heat} = Specific heat of milk in Btu/lb-°F
= 0.93³⁷

Density_{milk} = Density milk in lb/gal
= 8.7³⁸

ΔT = Required change in temperature (with precooler) in °F
= 19³⁹
Required change in temperature (without precooler) in °F
= 59⁴⁰

1000 = Conversion factor from watts to kilowatts

N_{Cows} = Number of cows
= Actual, if unknown use 90 cows⁴¹

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.

³⁶ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2

³⁷ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2

³⁸ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2

³⁹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

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

⁴¹ Entered from application form; default value based on 2007 AG Census in IA. Average number of cows per farm = 215,391/2,390 = 90, p. 393: http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf

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 applications⁴²
- 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-AGE-SCROL-V01-170101

SUNSET DATE: 1/1/2021

⁴² 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 an of reduced wattage heat lamps 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 standard wattage heat lamps of 175 watts.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of efficient lamp is 5,000 hours

DEEMED MEASURE COST

Incremental cost is assumed to be \$0⁴³.

LOADSHAPE

Loadshape C04 - Nonresidential Electric Heating

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\text{Annual kWh} = \frac{W_{\text{Base}} - W_{\text{Eff}}}{1000} \times \text{Hours} \times N_{\text{Units}}$$

Where:

*W*_{Base} = Wattage of baseline heat lamp
 = 175 watts⁴⁴

*W*_{eff} = Wattage of reduced wattage heat lamp
 = Actual if known, otherwise assume 125 watts⁴⁵

Hours = Annual heat lamp operating hours⁴⁶

⁴³ Internet search on www.gcsupply.com indicates no cost differential between 125 w and 175 w bulbs

⁴⁴The 175 watt baseline is based on standard practice based on discussions with IPL’s program manager Dave Warrington on October 14, 2015.

⁴⁵ 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

⁴⁶ 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

1,000 = 5,105 hours
= 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-V01-170101

SUNSET DATE: 1/1/2021

take off for power washing ect 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 milkhouse 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 14 years⁴⁷

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

$$\begin{aligned}
 \text{Heat Available} &= 6 \frac{\text{gal milk}}{\text{cow}} \frac{\text{day}}{\text{day}} \times 8.7 \frac{\text{lb}}{\text{gal milk}} \times 0.93 \frac{\text{Btu}}{\text{lb}^\circ\text{F}} \times \text{Milk } \Delta T \text{ }^\circ\text{F} \times 365.25 \text{ days} \\
 &= 1,045,438 \frac{\text{Btuh}}{\text{cow yr}} \text{ without precooler} \\
 &= 336,667 \frac{\text{Btuh}}{\text{cow yr}} \text{ with precooler} \\
 \text{Heat Storage} &= 2.2 \frac{\text{Gal H2O}}{\text{Cow/Day}} \times 8.34 \frac{\text{lb}}{\text{gal H2O}} \times 70^\circ\text{F H2O } \Delta T \times \frac{1}{0.90 \text{ E.F}} \times 365.25 \text{ days}
 \end{aligned}$$

⁴⁷ 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)

$$= 520,879 \frac{Btuh}{yr}$$

Where:

- E.F.* = Energy factor of the electric water heater
- ΔT = 59°F without precooler installed; 19°F with precooler installed

These equations 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	Btuh/yr	Limitation
No Precooler	468,791	Heat Storage
With Precooler	336,667	Heat Storage

$$kWh = \frac{Reclaimable\ Heat}{E.F} \times 0.000293 \frac{kWh}{Btuh}$$

Where:

- E.F.* = Energy factor of the electric water heater
= Actual, if unknown use 0.90⁴⁸
- Reclaimable Heat = Values Shown in Table 2
- 0.000293 = Conversion factor from Btuh to kWh

Table 2 – Heat Reclaimer Savings

Case	kWh/Cow
No precooler installed	152.7
Precooler installed	109.6

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 or natural gas water heaters only. Customers with propane 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

⁴⁸ Entered from application form; default value based on: IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-AGE-HTRE-V01-170101

SUNSET DATE: 1/1/2021

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. By replacing the heat lamps with hog heat mats reduces the amount of heat lost to the ambient air by heating directly beneath the piglets. Farrowing heat mat have a lower wattage draw than the typically heat lamp setup which results in annual energy savings.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure is 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”). 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 5⁴⁹ years.

DEEMED MEASURE COST

Incremental cost is assumed to be \$\$225⁵⁰

LOADSHAPE

Loadshape C04 - Non-Residential Electric Heating

Algorithm

CALCULATION OF ENERGY SAVINGS⁵¹

ELECTRIC ENERGY SAVINGS

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

Where:

- MatsSingle* = Number of single mats at 90 watts or less, actual
- MatsDouble* = Number of single mats at 180 watts or less , actual
- SavingsSingleMat* = 657 kWh/mat
- SavingsDoubleMat* = 1,315 kWh/mat
- Contoller = Number of Contollers, actual

⁴⁹Professional judgement

⁵⁰ 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 publically.

⁵¹All variable values come from: IPL Custom Farrowing Heat Mat Calculator

Controller Impact = 383 kWh/usage per controller

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

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

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

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

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

$$Crates_{single} = \frac{[(Crates_{Single-Row} * SingleWattage * SingleMat * Rows)]}{1000 \frac{Watts}{kWh}}$$

$$Crates_{double} = \frac{[(Crates_{double} * DoubleWattage * DoubleMat * Rows)]}{1000 \frac{Watts}{kWh}}$$

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

$$Hours_{Yr} = \left(365.25 * 24 * \frac{Days_{Farrowing}}{Days_{Farrowing} + Days_{Cleaning}} \right)$$

Where:

- CratesTotal = Number of crates
= 234
- HoursYr = Annual hours of operation
=5,105 hours⁵²
- FixtureCrate = Number of heat lamp fixtures per crate
=1.25
- LampFixture = Number of heat lamps per fixture
=1
- WattageLamp = Wattage of heat lamp
= 175
- 1000 Watts/kW = Constant, conversion factor for watts to kWh

⁵² 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 ect 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 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.

ControllerAdv	= Controller advantage =1
Rooms	= Number of rooms per farrowing barn =9
MSURoom	= Number of master sensor units (MSU) per room =1
MSUWattage	= Wattage of master sensor unit =75W
CratesSingle-Row	= Number of single crates per row =1
SingleWattage	= Wattage of a 14" x 60" farrowing heat mat = 90W
SingleMat	= Number of 14" x 60" farrowing heat mats per single crate = 1
Rows	= Number of rows per room =2
CratesDouble-Row	= Number of Double Crates per Row =12
DoubleWattage	= Wattage of a 24" x 60" farrowing heat mat =18
DoubleMat	= Number of a 24" x 60" farrowing heat matt =0.5
365	= Number of days per year
24	= Number of hours per day
DaysFarrowing	= Number of days per cycle the farrowing barn is used =21 ⁵³
DaysCleaning	= Number of days per cycle the farrowing barn is cleaned =3 ⁵⁴

SUMMER COINCIDENT PEAK DEMAND SAVINGS

No summer coincident peak demand savings for heating measures

⁵³ "Removing the piglets from the sow can occur anytime after 14 days of age. Many commercial operations wean pigs prior to 21 days of age." <http://extension.psu.edu/courses/swine/reproduction/farrowing-management>

⁵⁴ Industry standard is 3 days to properly disinfect farrowing stalls to get ready for the next group.

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-V01-170101

SUNSET DATE: 1/1/2021

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 2,000 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 years⁵⁵

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 below⁵⁶.

Tier (bushels per hour)	Tier (annual bushels)	Average Incremental cost
< 500	< 170,000	\$20,000.00
≥ 500 and < 1000	≥ 170,000 and < 330,000	\$30,000.00
≥ 1000 and < 2000	≥ 330,000 and < 670,000	\$40,000.00
≥ 2000 and < 3500	≥ 670,000 and < 1,200,000	\$70,000.00
≥ 3500 and ≤ 5000	≥ 1,200,000 and ≤ 1,700,000	\$100,000.00

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

⁵⁵ Estimate based on professional judgment

⁵⁶ Source: Version 9_9_15 Formatted Grain Dryer Prescriptive.xls

= Actual, if unknown use Table⁵⁷

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
= 0.075⁵⁸

$kWh_{Bushel\ new}$ = kWh usage per bushel for a new grain dryer
= 0.035⁵⁹

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-V01-170101

SUNSET DATE: 1/1/2021

⁵⁷ Alliant Energy Custom Rebate project data from 2012-2014

⁵⁸ Alliant Energy Custom Rebate project data from 2012-2014

⁵⁹ 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 unit with heating element 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 years⁶⁰.

DEEMED MEASURE COST

The incremental capital cost for the waterers are \$787.50:⁶¹,

LOADSHAPE

Loadshape C04 - Nonresidential Electric Heating

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

kWh/Waterer = 1104⁶²

N_{Units} = Number of waterers installed per farm

⁶⁰ Act on Energy Commercial Technical Reference Manual No. 2010-4. Typical warranty on waterers is 10 years.

⁶¹ Act on Energy Commercial Technical Reference Manual No. 2010-4.

⁶² Alliant's Global Energy Partners impact calculations in DSM Tracking, 2006 and is in agreement with IPL 2014 EEP filing

ANNUAL ENERGY DEMAND ALGORITHM:

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-V01-170101

SUNSET DATE: 1/1/2021

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 5⁶³ years

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

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

Where:

Hours	= hours irrigation system runs per season = 864 hrs/yr ⁶⁴
Acres	= Actual
Flow per Acre	= 5 gallons/minute/acre ⁶⁵
1715	= Conversion factor from PSI x GPM ((lb x gallons) / (sq. in x min)) to horsepower
Pump _{eff}	= Actual, if unknown use 0.70 ⁶⁶

⁶³ 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)

⁶⁴ KEMA, Appendix F Program Evaluations Group 1 Vol 2; page 353

⁶⁵ KEMA, Appendix F Program Evaluations Group 1 Vol 2; page 353.

⁶⁶ Appendix F Program Evaluations Group 1 Vol 2; page 354

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

FLH = Full Load Hours

= 6768⁶⁷

CF = Summer System Peak Coincidence Factor 79.3%⁶⁸

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-V01-170101

SUNSET DATE: 1/1/2021

⁶⁷ Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls

⁶⁸ 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.

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.⁶⁹

DEEMED MEASURE COST

Actual material and labor costs should be used.

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

ANNUAL ENERGY SAVINGS ALGORITHM:

Electric Savings kWh

$$Annual\ kWh = 16 * N_{Milking} * N_{Cows}$$

Where:

- 16 = Annual energy savings per cow per milking from VSD dairy vacuum pump (kWh/cow/milking)
= 16⁷⁰
- N_{Cows} = Number of milking cows per farm
= Actual, if unknown use 90⁷¹

⁶⁹ 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)

⁷⁰ 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.

⁷¹ Entered from application form; default value from 2007 AG Census in IA. Average number of cows per farm = 215,391/2,390 =

ANNUAL ENERGY DEMAND ALGORITHM:

Electric Demand Savings Peak kW

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

Where:

FLH = Full Load Hours
= 3689⁷²

CF = coincidence factor
= 0.793⁷³

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-V01-170101

SUNSET DATE: 1/1/2021

90, p. 393: http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf

⁷² Assumes average number of milkings per day is 2.8, average hours per milking is 3.7 hours and milking occurs 365 days a year. Source Milking System Air Consumption When Using a Variable Speed Vacuum Pump. Paper Number: 033014 An ASAE Meeting Presentation. July 2003

⁷³ 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 years⁷⁴

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 \$ as summarized in the table below.

LOADSHAPE

Loadshape NRE11 – Non-Residential Agriculture

Algorithm

CALCULATION OF SAVINGS

ANNUAL ENERGY SAVINGS ALGORITHM:

$$\text{Annual kWh} = \text{kWh/Cow} \times \text{NCows}$$

Where:

kWh/Cow = Per cow annual energy savings from plate-style milk pre cooler in kWh/cow/yr⁷⁵

Equipment Type	kWh/cow/year
Installed alone	76.2
Heat reclaimer installed	62.0
Scroll compressor installed	52.9
Both heat reclaimer and scroll compressor installed	65.0

⁷⁴ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, February 4, 2014

⁷⁵ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

Equipment Type	kWh/cow/year
Default if type not know ⁷⁶	66.5

NCows = Number of milking cows per farm
 = Actual, if unknown use 90⁷⁷

Savings Analysis:

$$kWh/Cow = \left(Days \times 0.93 \frac{Btu}{lb \cdot ^\circ F} \times 6 \frac{gal}{cow/day} \times 8.7 \frac{lb}{gal} \times \Delta T - Btuh \text{ of Heat Recovery} \right) \times \frac{1}{EER} \times \frac{1}{1000}$$

Days = Number of days in a year (365)⁷⁸
 6 = Gallons of milk per cow per day⁷⁹
 0.93 = Specific heat of milk⁸⁰
 8.7 = Density of milk (lbs/gal)⁸¹
 ΔT = Temperature reduction across precooler (40)⁸²
 Btuh of Heat Recovery = Difference in Btuh/yr recovered by heat reclaimer system (with and without precooler,) if installed (132,124)⁸³
 1000 = Conversion factor from watts to kilowatts⁸⁴
 EER = EER used to calculate kWh per cow depends on compressor type
 = if installed alone with unknown compressor type, use EER of 9.3⁸⁵
 = if installed with unknown compressor type and heat reclaimer, use EER of 9.3⁸⁶
 = if installed with scroll compressor, use EER of 10.9⁸⁷
 = If installed with scroll compressor and heat reclaimer use EER of 10.9⁸⁸

⁷⁶ 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.

⁷⁷ Entered from application form; default value from: 2007 AG Census in IA. Average number of cows per farm = 215,391/2,390 = 90, p. 393: http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf

⁷⁸ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

⁷⁹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 349.

⁸⁰ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 352.

⁸¹ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

⁸² IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

⁸³ Calculated from Table H-19 of IPL Energy Efficiency Programs 2009 Evaluation, KEMA; page 349 (constant defined in page 351 was listed incorrectly and was revised to reflect the correct value)

⁸⁴ IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2, page 351.

⁸⁵ Typical milk precooler 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.

⁸⁶ Typical milk precooler 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.

⁸⁷ Typical milk precooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The scroll compressor EER of 10.5 is from the Scroll Refrigerant Compressor measure efficient option for 2HP compressor.

⁸⁸ Typical milk precooler refrigeration systems are medium temperature and use a 2HP equivalent compressor. The scroll

ANNUAL ENERGY DEMAND ALGORITHM:

Electric Demand Savings Peak kW—Milk Precooler—Dairy Plate Cooler

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

Where:

H = full load hours

3689⁸⁹

CF = coincidence factor

= 0.79⁹⁰

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- V01-170101

SUNSET DATE: 1/1/2021

compressor EER of 10.5 is from the Scroll Refrigerant Compressor measure efficient option for 2HP compressor.

⁸⁹ Assumes average number of milkings per day is 2.8, average hours per milking is 3.7 hours and milking occurs 365 days a year. Source Milking System Air Consumption When Using a Variable Speed Vacuum Pump. Paper Number: 033014 An ASAE Meeting Presentation. July 2003

⁹⁰ Cadmus Loadshape analysis IA_Loadshapes_ WORKING DRAFT.xls

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)⁹¹ 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 GPM⁹² 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.⁹³

DEEMED MEASURE COST

The incremental installed cost for this measure is \$16⁹⁴ 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 retrofitted⁹⁵.

⁹¹ IPL program product data for 2014 Iowa Residential Energy Assessments.

⁹² DOE Energy Cost Calculator for Faucets and Showerheads:

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

⁹³ 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"

⁹⁴ 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)).

⁹⁵ 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

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

Where:

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

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	53% ⁹⁶

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

= Measured full throttle flow * 0.83 throttling factor⁹⁷

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 factor⁹⁸

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 ⁹⁹ (A)	Unit	Estimated % total building hot water use from Faucets ¹⁰⁰ (B)	Multiplier ¹⁰¹ (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

fixtures in a building, several variables must be incorporated.

⁹⁶ 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.

⁹⁷ 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

⁹⁸ 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

⁹⁹ Table 2-45 Chapter 49, Service Water Heating, 2007 ASHRAE Handbook, HVAC Applications.

¹⁰⁰ 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

¹⁰¹ 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 ⁹⁹ (A)	Unit	Estimated % total building hot water use from Faucets ¹⁰⁰ (B)	Multiplier ¹⁰¹ (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
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
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

EPG_{electric} = Energy per gallon of mixed water used by faucet (electric water heater)
 = $(\gamma_{\text{Water}} * 1.0 * (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{electric}} * 3412)$
 = 0.0822 kWh/gal if resistance tank (or unknown)¹⁰²
 = 0.0288 kWh/gal if heat pump water heater

Where:

- γ_{Water} = Specific weight of water (lbs/gallon)
= 8.33 lbs/gallon
- 1.0 = Heat Capacity of water (Btu/lb-°F)
- WaterTemp = Assumed temperature of mixed water
= 86F for Bath, 93F for Kitchen
- SupplyTemp = Assumed temperature of water entering building
= 56.5¹⁰³
- RE_{electric} = Recovery efficiency of electric water heater
= 98%¹⁰⁴ for electric resistance (or unknown)
= 280%¹⁰⁵ for heat pump water heaters

¹⁰² Assumes 50:50 kitchen and bathroom usage.

¹⁰³ 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.

¹⁰⁴ Electric water heaters have recovery efficiency of 98%: <http://www.ahridirectory.org/ahridirectory/pages/home.aspx>

¹⁰⁵ Since faucet aerator draws are unlikely to kick the unit into resistance mode, this assumes the unit is in heat pump mode during recovery. The value is based upon AHRI directory recovery efficiency for units that are not test in resistance mode.

3412 = Converts Btu to kWh (Btu/kWh)
 ISR = In service rate of faucet aerators
 =Assumed to be 1.0

Based on defaults provided above:¹⁰⁶

Building Type	ΔkWh		
	Resistance Tank	Heat Pump Tank	Unknown DHW
Small Office	44.9	15.7	23.8
Large Office	202.2	70.8	107.1
Fast Food Rest	172.3	60.3	91.3
Sit-Down Rest	283.5	99.2	150.3
Retail	65.6	23.0	34.8
Grocery	65.6	23.0	34.8
Warehouse	44.9	15.7	23.8
Elementary School	53.9	18.9	28.6
Jr High/High School	161.7	56.6	85.7
Health	295.3	103.4	156.5
Motel	32.8	11.5	17.4
Hotel	23.0	8.0	12.2
Other	89.8	31.4	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 * 0.479¹⁰⁷)/GPH

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 70F temp rise (126.5-56.5), 98% for resistance or 280% for heat pump water tanks recovery efficiency, and typical 12kW electric resistance storage tank¹⁰⁸.

= 68.8 if resistance tank, 196.6 if heat pump

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

¹⁰⁶ See "Commercial Faucet Aerator Calculations.xls" for details.

¹⁰⁷ 47.9% is the proportion of hot 126.5F water mixed with 56.5F supply water to give 90°F mixed faucet water.

¹⁰⁸ See "Calculation of GPH Recovery.xls" for more information.

Building Type	Annual Recovery Hours	
	Resistance Tank	Heat Pump Tank
Small Office	17.4	6.1
Large Office	78.3	27.4
Fast Food Rest	66.7	23.3
Sit-Down Rest	109.8	38.4
Retail	25.4	8.9
Grocery	25.4	8.9
Warehouse	17.4	6.1
Elementary School	20.9	7.3
Jr High/High School	62.7	21.9
Health	114.4	40.0
Motel	12.7	4.4
Hotel	8.9	3.1
Other	34.8	12.2

CF = Coincidence Factor for electric load reduction
 = Dependent on building type¹⁰⁹

Building Type	Coincidence Factor	
	Resistance Tank	Heat Pump Tank
Small Office	0.0045	0.0016
Large Office	0.0238	0.0083
Fast Food Rest	0.0114	0.0040
Sit-Down Rest	0.0250	0.0088
Retail	0.0058	0.0020
Grocery	0.0058	0.0020
Warehouse	0.0060	0.0021
Elementary School	0.0054	0.0019
Jr High/High School	0.0161	0.0056
Health	0.0196	0.0069
Motel	0.0009	0.0003
Hotel	0.0006	0.0002
Other	0.0119	0.0042

Based on defaults provided above:¹¹⁰

¹⁰⁹ 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.

¹¹⁰ See "Commercial Faucet Aerator Calculations.xls" for details.

Building Type	ΔkW		
	Resistance Tank	Heat Pump Tank	Unknown DHW
Small Office	0.0115	0.0040	0.0061
Large Office	0.0615	0.0215	0.0326
Fast Food Rest	0.0295	0.0103	0.0156
Sit-Down Rest	0.0647	0.0226	0.0343
Retail	0.0150	0.0052	0.0079
Grocery	0.0150	0.0052	0.0079
Warehouse	0.0154	0.0054	0.0082
Elementary School	0.0138	0.0048	0.0073
Jr High/High School	0.0415	0.0145	0.0220
Health	0.0505	0.0177	0.0268
Motel	0.0022	0.0008	0.0012
Hotel	0.0016	0.0006	0.0008
Other	0.0308	0.0108	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% ¹¹¹

EPG_gas = Energy per gallon of mixed water used by faucet (gas water heater)
 = (8.33 * 1.0 * (WaterTemp¹¹² - 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%¹¹³
 = 78% for buildings with storage tank, 59% if hot water through

¹¹¹ 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.

¹¹² Assumes 50:50 kitchen and bathroom usage.

¹¹³ 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.

central boiler or 69% if unknown¹¹⁴

100,000

= Converts Btus to Therms (Btu/Therm)

Other variables as defined above.

Based on defaults provided above:¹¹⁵

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
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 above¹¹⁶:

¹¹⁴ 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.

¹¹⁵ See “Commercial Faucet Aerator Calculations.xls” for details.

¹¹⁶ See “Commercial Faucet Aerator Calculations.xls” for details.

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

$$\Delta Gallons = \frac{GPM_base - GPM_low}{GPM_base} * Usage * ISR$$

Variables as defined above

Based on defaults provided above:¹¹⁷

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

¹¹⁷ See “Commercial Faucet Aerator Calculations.xls” for details.

N/A

MEASURE CODE: NR-HWE-LFFA-V01-170101

SUNSET DATE: 1/1/2020

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 is not recommended unless a thermostatic mixing valve is also present to prevent the potential for scalding due to the loss of thermal buffering in water volume when supply water temperature or line pressure changes suddenly¹¹⁸.

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.¹¹⁹

DEEMED MEASURE COST

The incremental installed cost for this measure is \$20¹²⁰ 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:

¹¹⁸ For more information see http://www.allianceforwaterefficiency.org/commercial_restroom_audit.aspx, <http://www.asse-plumbing.org/Scaldhazards.pdf>

¹¹⁹ 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.

¹²⁰ Direct-install price per showerhead assumes cost of showerhead (Market research average of \$7 and assess and install time of \$13 (20min @ \$40/hr).

$$\Delta kWh = \%ElectricDHW * ((GPM_base - GPM_low) * (L * SPD) * 365.25) * EPG_electric * ISR$$

Where:

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

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	53% ¹²¹

GPM_base = Flow rate of the baseline showerhead
 = Actual measured flow rate - If not measured, assume 2.5 GPM¹²²

GPM_low = Flow rate of the low-flow showerhead
 = Actual measured flow rate - If not measured, assume 1.5 GPM

(L * SPD) = Minutes of use per showerhead annually. Ideally, this should be calculated using the following:

L = Shower length in minutes with showerhead
 = 7.8 min¹²³

SPD = Showers Per Day for showerhead
 = Input estimate

= If it is not possible to provide a reasonable custom estimate, the following defaults can be used¹²⁴:

Building Type	Annual Minutes per Showerhead (L * SPD)
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

365.25 = Days per year, on average

EPG_electric = Energy per gallon of hot water supplied by electric

¹²¹ 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.

¹²² The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

¹²³ 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.

¹²⁴ 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.

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

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

Where:

γ_{Water} = Specific weight of water (lbs/gallon)
= 8.33 lbs/gallon

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

ShowerTemp = Assumed temperature of water
= 101°F¹²⁵

SupplyTemp = Assumed temperature of water entering house
= 56.5°F¹²⁶

RE_{electric} = Average Recovery efficiency of electric water heater
= 98%¹²⁷ for electric resistance (or unknown)
= 200%¹²⁸ for heat pump water heaters

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 with electric DHW where the number of showers is estimated at 3 per day:

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

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

¹²⁵ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

¹²⁶ 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.

¹²⁷ Electric water heaters have recovery efficiency of 98%: <http://www.ahridirectory.org/ahridirectory/pages/home.aspx>

¹²⁸ 200% 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 multiple shower draw would kick the unit in to resistance mode (98%). Note that the AHRI directory provides recovery efficiency ratings, some of which are >250% but most are rated at 100%. This is due to the rating test involving a large hot water draw, consistent with multiple showers.

$$= (\text{GPM}_{\text{base}} * L * \text{SPD} * 365.25 * 0.65^{129}) / \text{GPH}$$

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 70F temp rise (126.5-56.5), 98% recovery efficiency, and typical 12kW electric resistance storage tank¹³⁰.

= 68.8 if resistance tank, 196.6 if heat pump

CF = Coincidence Factor for electric load reduction

= 1.6%¹³¹

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:

$$\begin{aligned} \Delta \text{kW} &= (948.7 / 121) * 0.016 \\ &= 0.125 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

$$\Delta \text{Therms} = \% \text{FossilDHW} * (\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) * (L * \text{SPD}) * 365.25 * \text{EPG}_{\text{gas}} * \text{ISR}$$

Where:

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

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	47% ¹³²

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

$$= (8.33 * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{gas}} * 100,000)$$

= 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

¹²⁹ 65.0% is the proportion of hot 125F water mixed with 56.5F supply water to give 101F shower water.

¹³⁰ See "Calculation of GPH Recovery.xls" for more information.

¹³¹ 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 $4.23 / 260 = 0.016$.

¹³² 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.

100,000

central boiler or 69% if unknown¹³³

= Converts Btus to Therms (Btu/Therm)

Other variables as defined above.

For example, for a direct-installed 1.5 GPM showerhead in an office 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 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

$$\Delta\text{Gallons} = (\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) * (L * \text{SPD}) * 365.25 * \text{ISR}$$

Variables as defined above

For example, for a direct-installed 1.5 GPM showerhead in an office 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

¹³³ Water heating in multifamily buildings is often provided by a larger central boiler. An average efficiency of 0.69 is used for this analysis as a default for multifamily buildings where the water heating system is unknown.

MEASURE CODE: NR-HWE-LFSH-V01-170101

SUNSET DATE: 1/1/2020

3.2.3 Gas Hot Water Heater

DESCRIPTION

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

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

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must fulfill the Utilities’ minimum efficiency criteria.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a new standard gas water heater of same type as existing, meeting the Federal Standard. If existing type is unknown, assume Gas Storage Water Heater.

Equipment Type	Size Category	Federal Standard Minimum Efficiency ¹³⁴
Gas Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.675 – (0.0015 * Rated Storage Volume in Gallons)
	>55 gallon tanks ¹³⁵	0.8012 – (0.00078 * Rated Storage Volume in Gallons)
Gas Storage Water Heaters > 75,000 Btu/h	< 4000 Btu/h/gal	80% E _t Standby Loss: (Q/800 + 110vV)
Gas Tankless Water Heaters >50,000 Btu/h and <200,000 Btu/h	< 4000 Btu/h/gal and <2 gal tank	0.82 – (0.0019 * Rated Storage Volume in Gallons)
Gas Tankless Water Heaters ≥200,000 Btu/h	≥ 4000 Btu/h/gal and <10 gal tank	80% E _t
Gas Tankless Water Heaters ≥200,000 Btu/h	≥ 4000 Btu/h/gal and ≥10 gal tank	80% E _t Standby Loss: (Q/800 + 110vV)

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for gas water heaters is assumed to be 15 years for storage heaters and 20 years for tankless water heaters.¹³⁶

DEEMED MEASURE COST

The full install cost and incremental cost assumptions are provided below. Actual costs should be used where available¹³⁷:

¹³⁴ ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.

¹³⁵ It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline.

¹³⁶ Based on DEER 2008 assumptions for high efficiency commercial storage water heaters and instantaneous water heaters.

¹³⁷ 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.

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

LOADSHAPE

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{Water} * 1 * \left(\frac{1}{EF_{base}} - \frac{1}{EF_{Eff}} \right)}{100,000}$$

Where:

- T_{out} = Unmixed Outlet Water Temperature
- = custom, otherwise assume 140¹³⁸

¹³⁸ 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.

T_{in} = Inlet Water Temperature
 = custom - otherwise assume 56.5¹³⁹

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 water heater capacity
 = Consumption/cap * Capacity

Where:

Consumption/cap = Estimate of consumption per gallon of tank capacity, dependent on building type:¹⁴⁰

Building Type	Consumption/cap
Grocery, Convenience, and Restaurant	803
Lodging, Hospital, and Multifamily	630
Health, Church, Warehouse	433
Education, Office, and Retail	594
Industrial	558
Agriculture	558
Average Non Residential	558

Capacity = Capacity of hot water heater
 = Actual¹⁴¹

2. Consumption by Facility Size¹⁴²

Building Type	Gallons hot water per unit per day	Unit	Units/1000 ft ²	Days per year	Gallons/1000 ft ²
Small Office	1	person	2.3	250	575
Large Office	1	person	2.3	250	575
Fast Food Rest	0.7	meal/day	784.6	365	200,458
Sit-Down Rest	2.4	meal/day	340	365	297,840
Retail	2	employee	1	365	730
Grocery	2	employee	1.1	365	803
Warehouse	2	employee	0.5	250	250

¹³⁹ 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.

¹⁴⁰ Based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2003) 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. VEIC consider these relatively conservative estimates and consider this may be a good variable for future evaluation.

¹⁴¹ If the replaced unit is a tankless water heater, an estimate will need to be made of the required storage tank for the application.

¹⁴² Osman Sezgen and Jonathan G. Koomey. Lawrence Berkeley National Laboratory 1995; "Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting". December 1995.

Building Type	Gallons hot water per unit per day	Unit	Units/1000 ft ²	Days per year	Gallons/1000 ft ²
Elementary School	0.6	person	9.5	200	1,140
Jr High/High School	1.8	person	9.5	200	3,420
Health	90	patient	3.8	365	124,830
Motel	20	room	5	365	36,500
Hotel	14	room	2.2	365	11,242
Other	1	employee	0.7	250	175

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

= 8.33 lbs/gal

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

EF_{base} = Rated efficiency of baseline water heater expressed as Energy Factor (EF) or Thermal Efficiency (E_t);

Equipment Type	Size Category	Federal Standard Minimum Efficiency
Gas Storage Water Heaters ≤ 75,000 Btu/h	≤55 gallon tanks	0.675 – (0.0015 * Rated Storage Volume in Gallons)
	>55 gallon tanks ¹⁴³	0.8012 – (0.00078 * Rated Storage Volume in Gallons)
Gas Storage Water Heaters > 75,000 Btu/h	< 4000 Btu/h/gal	80% E_t Standby Loss: (Q/800 + 110√V)
Gas Tankless Water Heaters >50,000 Btu/h and <200,000 Btu/h	< 4000 Btu/h/gal and <2 gal tank	0.82 – (0.0019 * Rated Storage Volume in Gallons)
Gas Tankless Water Heaters ≥200,000 Btu/h	≥ 4000 Btu/h/gal and <10 gal tank	80% E_t
Gas Tankless Water Heaters ≥200,000 Btu/h	≥ 4000 Btu/h/gal and ≥10 gal tank	80% E_t Standby Loss: (Q/800 + 110√V)

EF_{eff} = Rated efficiency of efficient water heater expressed as Energy Factor (EF) or Thermal Efficiency (E_t)

= 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.

$$\Delta Therms_{Standby} = \frac{(SL_{base} - SL_{eff}) * 8766}{100,000}$$

Where:

SL_{base} = Standby loss of baseline unit

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

Q = Nameplate input rating in Btu/h

V = Rated volume in gallons

¹⁴³ It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to high baseline.

SL_{eff} = Nameplate standby loss of new water heater, in BTU/h
 8766 = Hours per year

For example, for a 95% Thermal Efficiency, 130,000 Btu/hr, 100 gallon storage unit with rated standby loss of 1079 BTU/h installed in a restaurant:

$$\Delta Therms = ((140 - 56.5) * (803 * 100) * 8.33 * 1 * (1/0.8 - 1/0.95))/100,000 = 110.2 \text{ Therms}$$

$$\Delta Therms_{Standby} = (((130000/800 + 110 * \sqrt{100}) - 1079) * 8766)/100000 = 16.1 \text{ Therms}$$

$$\Delta Therms_{Total} = 110.2 + 16.1 = 126.3 \text{ Therms}$$

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:

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

Where:

$\Delta Therms$ = 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 1079 BTU/h installed in a restaurant:

$$\Delta PeakTherms = 126.3 / 365.25 = 0.3458 \text{ Therms}$$

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 \$100.¹⁴⁴

MEASURE CODE: NR-HWE-GHWH-V01-170101

SUNSET DATE: 1/1/2021

¹⁴⁴ 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: TOS, RF, NC. 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 years¹⁴⁵.

DEEMED MEASURE COST

The assumed measure cost is \$1,200 per pump.¹⁴⁶

LOADSHAPE

Loadshape NREW08 – Nonresidential Electric Hot Water – Multifamily

Loadshape NRGW08 – Nonresidential Gas Hot Water - Multifamily

Algorithm

CALCULATION OF ENERGY SAVINGS¹⁴⁷

Savings shown are per pump.

ELECTRIC ENERGY SAVINGS

Deemed at 651 kWh¹⁴⁸.

¹⁴⁵ 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.

¹⁴⁶ Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation Public project report*. Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.

¹⁴⁷ See Illinois_Statewide_TRM_Workpaper_Demand Control Central DHW for more details

¹⁴⁸ 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

Summer coincident peak demand savings are expected to be negligible.

NATURAL GAS SAVINGS¹⁴⁹

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

EXAMPLE

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:

$$\begin{aligned} \Delta\text{Therms} &= \text{Therm impact calculated above} \\ 365.25 &= \text{Days per year} \end{aligned}$$

EXAMPLE

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-V01-170101

SUNSET DATE: 1/1/2023

¹⁴⁹ 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 ¹⁵⁰

DEEMED MEASURE COST

Based on square footage and whether the cover is manually operated or automatic:

\$ / Sqft ¹⁵¹	
Manually Operated	Automatic
\$1.50	\$6.50

LOADSHAPE

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

¹⁵⁰ 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

¹⁵¹ Based on the average costs used by the U.S. DOE's Energy Smart Pools software

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

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 location¹⁵²

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

¹⁵² 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.

= 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:

- Sqft = surface area of the pool in ft²
= 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 ft³
- 12 = inches per foot
- 0.3¹⁵³ = 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-V01-170101

SUNSET DATE: 1/1/2023

¹⁵³ 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 25 years.¹⁵⁴

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 140¹⁵⁵

¹⁵⁴ Conservative estimate based on product manufacturer published expected lifetime.

¹⁵⁵ 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

T_{in} = Inlet Water Temperature to the DHW system
 = Actual, otherwise assume 56.5¹⁵⁶

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:

3. Consumption per water heater capacity
 = Consumption/cap * Capacity

Where:

Consumption/cap = Estimate of consumption per gallon of tank capacity, dependent on building type:¹⁵⁷

Building Type	Consumption/cap
Grocery, Convenience Store, and Restaurant	803
Lodging, Hospital, and Multifamily	630
Health Clinic, Church, Warehouse	433
Education, Office, and Retail	594
Industrial	558
Agriculture	558
Average Non Residential	558

Capacity = Capacity of hot water heater
 = Actual¹⁵⁸

4. Consumption by Facility Size¹⁵⁹

Building Type	Gallons hot water per unit per day	Unit	Units/1000 ft ²	Days per year	Gallons/1000 ft ²
Small Office	1	person	2.3	250	575
Large Office	1	person	2.3	250	575
Fast Food Rest	0.7	meal/day	784.6	365.25	200,458
Sit-Down Rest	2.4	meal/day	340	365.25	297,840
Retail	2	employee	1	365.25	730
Grocery	2	employee	1.1	365.25	803

degrees F and 140 degrees for applications like laundry or dishwashing.

¹⁵⁶ 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.

¹⁵⁷ Based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2003) 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. VEIC consider these relatively conservative estimates and consider this may be a good variable for future evaluation.

¹⁵⁸ If the replaced unit is a tankless water heater, an estimate will need to be made of the required storage tank for the application.

¹⁵⁹ Osman Sezgen and Jonathan G. Koomey. Lawrence Berkeley National Laboratory 1995; "Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting". December 1995.

Building Type	Gallons hot water per unit per day	Unit	Units/1000 ft ²	Days per year	Gallons/1000 ft ²
Warehouse	2	employee	0.5	250	250
Elementary School	0.6	person	9.5	200	1,140
Jr High/High School	1.8	person	9.5	200	3,420
Health	90	patient	3.8	365.25	124,830
Motel	20	room	5	365.25	36,500
Hotel	14	room	2.2	365.25	11,242
Other	1	employee	0.7	250	175

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%¹⁶⁰ 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
 = Actual if known - if not, assume:
 = 0.98¹⁶¹

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

$$\Delta kWh = (140 - 56.5) * (803 * 100) * 8.33 * 1 * 0.25 / (3,412 * 0.98)$$

$$= 4,175.9 \text{ kWh}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

¹⁶⁰ 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

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

Where:

- Hours = 8,766
- CF = Summer Peak Coincidence Factor for measure
- = 1

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

$$\begin{aligned} \Delta kW &= 4,175.9 / 8,766 * 1 \\ &= 0.48 \text{ kW} \end{aligned}$$

NATURAL GAS SAVINGS

For sites with natural gas DHW:

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

Where:

- 100,000 = Converts Btu to Therms
- RE_{gas} = Recovery efficiency of gas DHW system
- = Actual if known - if not, assume:
- = 78%¹⁶²

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:

$$\begin{aligned} \Delta Therms &= (140 - 56.5) * (803 * 100) * 8.33 * 1 * .25 / (100,000 * .85) \\ &= 164.3 \text{ Therms} \end{aligned}$$

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:

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

Where:

- ΔTherms = Therm impact calculated above

¹⁶² 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%.

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:

$$\Delta\text{PeakTherms} = 164.3 / 365.25$$

$$= 0.4498 \text{ Therms}$$

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-V01-170101

SUNSET DATE: 1/1/2023

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.

To calculate the EFLH by building type and climate zone provided below, VEIC created eQuest models 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 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).

Building Type	Burlington		Des Moines		Mason City		Weighting Factors for Nonresidential Average ¹⁶³
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	
Convenience	785	1477	1071	1351	1224	1128	0%
Education	968	1059	1300	937	1497	712	9%
Grocery	511	1975	737	1735	963	1483	0%
Health	1021	1169	1413	1064	1529	896	0%
Hospital	906	1843	1073	1673	1379	1363	0%
Industrial	849	1185	1183	1063	1275	856	0%
Lodging	1396	1503	1703	1355	1900	1084	0%
Multifamily	1396	1503	1703	1355	1900	1084	0%
Office - Large	1351	1227	1491	1143	1616	972	0%
Office - Small	1290	1094	1495	981	1673	787	26%
Religious	1322	1109	1796	1031	1873	797	16%
Restaurant	1036	1325	1247	1176	1381	956	7%
Retail - Large	893	1209	1303	1078	1394	861	5%
Retail - Small	1200	1179	1608	1039	1768	843	11%
Warehouse	1205	954	1440	866	1627	694	26%
Nonresidential Average	1197	1087	1497	979	1654	779	N/A

¹⁶³ 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.

3.3.1 Boiler

DESCRIPTION

To qualify for this measure, the installed equipment must be replacement of an existing boiler at the end of its service life, <300,000 Btu/hr 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.

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 <300,000 Btu/hr used for space heating, not process, and boiler AFUE 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 <300,000 Btu/hr used for space heating, not process, meeting the federal equipment standard of 82%¹⁶⁴.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years¹⁶⁵.

DEEMED MEASURE COST

The incremental install cost for this measure is provided below, dependent on efficiency¹⁶⁶:

AFUE	Full Install Cost	Incremental Install Cost
82%	\$3,835	n/a
85%	\$4,468	\$633
86%	\$5,264	\$1,429
87%	\$5,276*	\$1,441
88%	\$5,397*	\$1,562
89%	\$5,518*	\$1,683
90%	\$5,638*	\$1,803
91%	\$5,583	\$1,748
92%	\$5,734*	\$1,899

¹⁶⁴ 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.

¹⁶⁵ U.S. Department of Energy, "Chapter 8 Life Cycle Cost and Payback Period Analysis," Residential Furnaces and Boilers Technical Support Document, 2007. Table 8.3.3.

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf

¹⁶⁶ Based on data provided in Federal Appliance Standards, Chapter 8.3, of DOE Technical Support Documents; Table 8.5.6 LCC and PBP Results for Hot-Water Gas Boilers (High Cost). Where efficiency ratings are not provided, the values are interpolated from those that are and market with an *. See "Boiler_DOE Chapter 8.xls" for more information.

AFUE	Full Install Cost	Incremental Install Cost
93%	\$5,885*	\$2,050
94%	\$6,036*	\$2,201
95%	\$6,188*	\$2,353
96%	\$6,339*	\$2,504
97%	\$6,490*	\$2,655
98%	\$6,641*	\$2,806
99%	\$6,792	\$2,957

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

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

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 in Annual Fuel Utilization Efficiency Rating (AFUE).
= 82%¹⁶⁷

EfficiencyRating(EE) = Efficient equipment efficiency rating in Annual Fuel Utilization Efficiency Rating (AFUE)
= Actual

100,000 = Conversion of Btu to Therms

¹⁶⁷ 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.

For example, for a 150,000 Btu/hr water boiler meeting AFUE 90% in Des Moines at a large office building:

$$\begin{aligned} \Delta\text{Therms} &= 1491 * 150,000 * (0.90-0.82)/(0.82 * 100,000) \\ &= 218.2 \text{ Therms} \end{aligned}$$

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 ¹⁶⁸
Convenience	0.016310
Education	0.013261
Grocery	0.021811
Health	0.011071
Hospital	0.013578
Industrial	0.014240
Lodging	0.008752
Multifamily	0.008752
Office - Large	0.010094
Office - Small	0.011695
Religious	0.011745
Restaurant	0.010510
Retail - Large	0.014243
Retail - Small	0.011861
Warehouse	0.012010
Nonresidential Average ¹⁶⁹	0.012000

For example, for a 150,000 Btu/hr water boiler meeting AFUE 90% in Des Moines at a large office building:

$$\begin{aligned} \Delta\text{Peak Therms} &= 218.2 * 0.010094 \\ &= 2.2025 \text{ Therms} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-BOIL-V01-170101

SUNSET DATE: 1/1/2022

¹⁶⁸ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

¹⁶⁹ For weighting factors, see HVAC variable table in section 3.3.

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.

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%¹⁷⁰

DEFINITION OF MEASURE LIFE

The expected equipment measure life is assumed to be 15 years¹⁷¹.

DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below¹⁷²:

AFUE	Full Install Cost	Incremental Install Cost
85%	\$2,392	n/a
86%	\$2,461*	\$69
87%	\$2,530*	\$138
88%	\$2,599*	\$207
89%	\$2,668*	\$276
90%	\$2,737	\$345
91%	\$2,848*	\$456
92%	\$2,915*	\$523
93%	\$3,249*	\$857
94%	\$3,449*	\$1,057
95%	\$3,649*	\$1,257

¹⁷⁰ 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.

¹⁷¹ CEE Residential Heating and Cooling Systems. Initiative Description. January 13, 2015. Page 9

¹⁷² Based on data provided in Federal Appliance Standards, Chapter 8.3 of DOE Technical Support Documents, Table 8.5.1 LCC and PBP Results for Non-weatherized Gas Furnaces. Where efficiency ratings are not provided, the values are interpolated from those that are and market with an *. See "Furnace_DOE Chapter 8.xls" for more information.

AFUE	Full Install Cost	Incremental Install Cost
96%	\$3,894	\$1,502

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
- 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 a small office building in Des Moines:

$$\begin{aligned} \Delta Therms &= (1495 * 150,000 * (0.92/0.85 - 1)) / 100,000 \\ &= 184.7 Therms \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

Δ Therms = Therm impact calculated above
 GCF = Gas Coincidence Factor for Heating

Building Type	GCF ¹⁷³
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ¹⁷⁴	0.012386

For example, for a 150,000 Btu/hr 92% efficient furnace installed stallation at a small office building in Des Moines:

$$\Delta\text{PeakTherms} = 184.7 * 0.011789$$

$$= 2.1774 \text{ Therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-FRNC-V01-170101

SUNSET DATE: 1/1/2019

¹⁷³ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

¹⁷⁴ 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years¹⁷⁵.

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:

$$\text{Cost} = \$0.29 * \text{Watts} + \$36.5^{176}$$

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

Loadshape NREH01:16 - Nonresidential Electric Heat (by Building Type)

Algorithm

CALCULATION OF ENERGY SAVINGS

¹⁷⁵ 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

¹⁷⁶ Incremental costs established by comparing prices as listed on grainger.com 10/25/2015. See “ECM costs.xlsx” for complete analysis methodology.

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 Watts
- LF_{base} = Load Factor of baseline motor at fan design CFM
= 65%¹⁷⁷
- Hours = Annual motor operating hours
= 4000¹⁷⁸
- SF = Savings factor
= 0.2¹⁷⁹
- η_{basemotor} = Efficiency rating of the baseline motor
= 0.85¹⁸⁰

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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

¹⁷⁷ 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.

¹⁷⁸ Total number of hours furnaces are expected to be operating during the heating season. Considered a conservative estimate, based on eQUEST modeling results for Small Offices, Religious, Warehouse, Small Retail and Restaurants, which cumulatively represent the majority of expected market.

¹⁷⁹ 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.

¹⁸⁰ 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.

MEASURE CODE: NR-HVC-FBLM-V01-170101

SUNSET DATE: 1/1/2023

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 of 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 of 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.¹⁸¹

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 products¹⁸² and \$935.98 per ton for CEE Tier 2 and higher class products.¹⁸³ 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

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:

¹⁸¹Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

¹⁸² For specification details see; <https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0>

¹⁸³ NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}} \right)}{1000} \right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}} \right)}{1000} \right]$$

Where:

- EFLH_{cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use.
- Capacity_{cool} = Cooling 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.¹⁸⁴
- SEER_{ee} = Seasonal Energy Efficiency Ratio 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 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

For units with cooling capacities equal to or greater than 65 kBtu/hr and all water source units:

$$\Delta kWh = \left[\frac{EFLH_{cool} * Capacity_{cool} * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right)}{1000} \right] + \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{COP_{base}} - \frac{1}{COP_{ee}} \right)}{3412} \right]$$

Where:

- 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
- 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.

¹⁸⁴ International Energy Conservation Code (IECC) 2012

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.3.4 Heat Pump Systems

= Actual installed

All other variables as defined above.

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 ^a
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 5 ton cooling unit at a restaurant in Des Moines with 60,000 Btu/h heating capacity with an EER of 14 and an HSPF of 9 saves

$$= [(60,000) * [(1/13) - (1/14)] * 1176] + [(60,000) * [(1/7.7) - (1/9)] * 1247]/1000$$

$$= 1791 \text{ kWh}$$

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 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 above for values. Since IECC 2012 does not provide EER requirements for air-cooled heat pumps < 65 kBtu/hr, 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 ¹⁸⁵
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ¹⁸⁶	79.8%

For example a 5 ton cooling unit at a restaurant in Des Moines with 60,000 Btu/h heating capacity with an EER of 14 and an HSPF of 9 saves

$$\begin{aligned} \Delta kW &= [(60,000) * [(1/13) - (1/14)]] / 1000 * .915 \\ &= 0.30 \text{ kW} \end{aligned}$$

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-V01-170101

SUNSET DATE: 1/1/2019

¹⁸⁵ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

¹⁸⁶ 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.

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 an Air Source Heat Pump meeting the Federal Standard efficiency level: 14 SEER, 8.2 HSPF, and 11.8¹⁸⁷ EER.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected equipment measure life is assumed to be 15 years¹⁸⁸.

DEEMED MEASURE COST

The actual installed cost of the Geothermal Source Heat Pump should be used (default of \$3,957 per ton¹⁸⁹), minus the assumed installation cost of the baseline equipment (\$1,936 per ton for ASHP¹⁹⁰).

LOADSHAPE

Loadshape NREP01:16 - Nonresidential Electric Heat Pump (by Building Type)

¹⁸⁷ 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.

¹⁸⁸ System life of indoor components as per 'Packaged AC/HP' lifetime assumption from Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.

¹⁸⁹ Based on data provided in 'Results of Home geothermal and air source heat pump rebate incentives documented by IL electric cooperatives'.

¹⁹⁰ Based on data provided on Home Advisor website, providing national average ASHP cost based on 2465 cost submittals. <http://www.homeadvisor.com/cost/heating-and-cooling/install-a-heat-pump/>

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = [Cooling\ savings] + [Heating\ savings]$$

$$= \left[\frac{EFLH_{Cool} * Capacity_{Cool} * \left(PLF_{Cool} * \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{EE-PL}} \right) + FLF_{Cool} * \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{EE-FL}} \right) \right)}{1000} \right]$$

$$+ \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(PLF_{Heat} * \left(\frac{1}{HSPF_{Base}} - \frac{1}{(COP_{EE-PL} * 3.412)} \right) + FLF_{Heat} * \left(\frac{1}{HSPF_{Base}} - \frac{1}{(COP_{EE-FL} * 3.412)} \right) \right)}{1000} \right]$$

Where:

- EFLH_{Cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use
- Capacity_{Cool} = Cooling Capacity of Geothermal Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000 Btu/hr)
- PLF_{Cool} = Part load cooling mode operation
= 0.85¹⁹¹ if variable speed GSHP
= 0 if single/constant speed GSHP
- FLF_{Cool} = Full load cooling mode operation factor
= 0.15 if variable speed GSHP
= 1 if single/constant speed GSHP
- EER_{Base} = SEER Efficiency of new baseline ASHP unit
= 11.8¹⁹²
- EER_{EE- PL} = Part Load EER Efficiency of efficient GSHP unit
= Actual installed
- EER_{EE- FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit
= Actual installed
- EFLH_{Heat} = Equivalent Full Load Hours for heating are provided in section 3.3 HVAC End Use
- Capacity_{Heat} = Full Load Heating Capacity of Geothermal Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000 Btu/hr)

¹⁹¹ 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.

¹⁹² 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.

- PLF_{Heat} = Part load heating mode operation
= 0.5¹⁹³ if variable speed GSHP
= 0 if single/constant speed GSHP
- FLF_{Heat} = Full load heating mode operation factor
= 0.5 if variable speed GSHP
= 1 if single/constant speed GSHP
- HSPF_{Base} = Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)
= 8.2¹⁹⁴
- COP_{EE - PL} = Part Load Coefficient of Performance of efficient unit
= Actual Installed
- COP_{EE - FL} = Full Load Coefficient of Performance of efficient unit
= Actual Installed
- 3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).

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:

- EER_{base} = EER Efficiency of new baseline unit
= 11.8¹⁹⁵
- 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 ¹⁹⁶
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%

¹⁹³ 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.

¹⁹⁴ Minimum Federal Standard as of 1/1/2015.

¹⁹⁵ 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.

¹⁹⁶ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ¹⁹⁶
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ¹⁹⁷	79.8%

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- HVAC-GSHP-V01-170101

SUNSET DATE: 1/1/2019

¹⁹⁷ For weighting factors, see HVAC variable table in section 3.3.

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 of 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 of 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.¹⁹⁸

DEEMED MEASURE COST

The incremental capital cost for this measure is based upon capacity and efficiency level (defined by CEE specifications¹⁹⁹), as outlined in the following table:²⁰⁰

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)

¹⁹⁸ Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

¹⁹⁹ For specification details see; <https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0>

²⁰⁰ NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

Algorithm

CALCULATION OF SAVINGS

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 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 Capacity of new equipment in Btu/hr (note 1 ton = 12,000Btu/hr)
= Actual installed
- SEER_{base} = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh); see table below for default values²⁰¹:
- SEER_{ee} = Seasonal Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh)
= Actual installed
- IEER_{base} = Integrated Energy Efficiency Ratio of baseline unit (kBtu/kWh); see table below for default values²⁰²:
- 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

²⁰¹ International Energy Conservation Code (IECC) 2012

²⁰² International Energy Conservation Code (IECC) 2012

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.3.6 Single-Package and Split System Unitary Air Conditioners

**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	AHRI 340/360		
		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
		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		12.5 EER 12.7 IEER	
All other			Split System and Single Package	10.8 EER 11.0 IEER	12.3 EER 12.5 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	12.2 EER 12.4 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	12.0 EER 12.2 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 SEER of 15 at a small retail building in Burlington would save

$$\begin{aligned} \Delta kWh &= (60,000) * [(1/13) - (1/15)] / 1000 * 1179 \\ &= 725.5 kWh \end{aligned}$$

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. 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 × SEER² + 1.12 × 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 × SEER² + 1.12 × SEER

= Actual installed

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ²⁰³
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ²⁰⁴	79.8%

For example a 5 ton air cooled split system with a SEER of 15 (EER unknown) at a small retail building in Burlington would save:

$$\begin{aligned}
 \text{EER}_{\text{base}} &= -0.02 \times 13^2 + 1.12 \times 13 \\
 &= 11.2 \text{ EER} \\
 \text{EER}_{\text{ee}} &= -0.02 \times 15^2 + 1.12 \times 15 \\
 &= 12.3 \text{ EER} \\
 \Delta \text{kW} &= (60,000 * [(1/11.2) - (1/12.3)] / 1000 * 0.877 \\
 &= 0.4202 \text{ kW}
 \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

MEASURE CODE: NR-HVC-SPUA-V01-170101

SUNSET DATE: 1/1/2020

²⁰³ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

²⁰⁴ 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 503.2.3(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 503.2.3(7).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years²⁰⁵.

DEEMED MEASURE COST

The incremental capital cost for this measure is provided below²⁰⁶.

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	\$229	\$457	\$701	\$838
>= 50 and <100	\$114	\$229	\$350	\$419
>= 100 and <150	\$76	\$152	\$234	\$279
>= 150 and <200	\$47	\$93	\$143	\$171
>= 200	\$23	\$47	\$71	\$85

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	\$76	\$126	n/a	n/a
>= 50 and <100	\$38	\$63	n/a	n/a
>= 100 and <150	\$25	\$42	n/a	n/a
>= 150 and <200	\$0	\$61	\$122	\$183
>= 200	\$0	\$31	\$61	\$92

²⁰⁵ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008 .

²⁰⁶ NEEP Incremental Cost Study (ICS) Final Report – Phase 2, January 2013.

Water cooled, electrically operated, positive displacement (reciprocating) (\$/ton)			
Capacity (tons)	> .60 kW/ton	.60 and > .58 kW/ton	.58 kw/ton and less
< 100	\$73	\$110	\$183
>= 100 and <150	\$49	\$73	\$122
>= 150 and <200	\$37	\$55	\$92
>= 200 and <300	\$61	\$91	\$152
>= 300	\$30	\$46	\$76

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 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}²⁰⁷ = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)²⁰⁸
= 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 a warehouse with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) in Des Moines would save:

$$\begin{aligned} \Delta kWh &= 100 * ((0.96) - (0.86)) * 866 \\ &= 8,660 kWh \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = TONS * ((PE_{base}) - (PE_{ee})) * CF$$

Where:

²⁰⁷ 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.

²⁰⁸ Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRnetl.org. <http://www.ahrinet.org/>

- 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 ²⁰⁹
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ²¹⁰	79.8%

For example, a 100 ton air-cooled electrically operated chiller in a 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 Des Moines would save:

$$\begin{aligned} \Delta kW &= 100 * ((1.26) - (1.0)) * 0.779 \\ &= 20.25 \text{ kW} \end{aligned}$$

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

²⁰⁹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

²¹⁰ For weighting factors, see HVAC variable table in section 3.3.

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

$kW/ton = 12 / EER$

$kW/ton = 12 / (COP \times 3.412)$

$COP = EER / 3.412$

$COP = 12 / (kW/ton) / 3.412$

$EER = 12 / kW/ton$

$EER = COP \times 3.412$

Baseline Efficiency Values by Chiller Type and Capacity²¹¹

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.

²¹¹ 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	≥ 10.4	≥ 9.562	≥ 12.500	NA	NA	AHRI 550/590
	≥ 150 tons	EER		16	≥ 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	≤ 0.790	≤ 0.676	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	
	≥ 75 tons and < 150 tons	kW/ton			≤ 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	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596					
	≥ 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-V01-170101

SUNSET DATE: 1/1/2020

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 15 years.²¹²

Remaining life of existing equipment is assumed to be 5 years²¹³

DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this equipment is estimated to be \$84/ton.²¹⁴

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 ton²¹⁵.

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be \$963 per ton²¹⁶. This cost should be discounted to present value using the utilities' discount rate.

²¹² Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

²¹³ Standard assumption of one third of effective useful life.

²¹⁴ DEER 2008. This assumes that baseline shift from IECC 2006 to IECC 2012 carries the same incremental costs. Values should be verified during evaluation

²¹⁵ Based on DCEO – IL PHA Efficient Living Program data.

²¹⁶ Based on subtracting TOS incremental cost from the DCEO data.

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:

$$\text{PTAC } \Delta \text{kWh}^{217} = \text{Annual kWh Savings}_{\text{Cool}}$$

$$\text{PTHP } \Delta \text{kWh} = \text{Annual kWh Savings}_{\text{Cool}} + \text{Annual kWh Savings}_{\text{Heat}}$$

$$\Delta \text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{Cool}} * \left(\frac{1}{\text{EER}_{\text{base}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1000} \right]$$

$$\Delta \text{kWh Savings}_{\text{heat}} = \left[\frac{\text{EFLH}_{\text{Heat}} * \text{Capacity}_{\text{Heat}} * \left(\frac{1}{\text{COP}_{\text{base}}} - \frac{1}{\text{COP}_{\text{ee}}} \right)}{3412} \right]$$

Early Replacement:

$$\Delta \text{kWh for remaining life of existing unit (1}^{\text{st}} \text{ 5years)} = \text{Annual kWh Savings}_{\text{Cool}} + \text{Annual kWh Savings}_{\text{Heat}}$$

$$\Delta \text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{Cool}} * \left(\frac{1}{\text{EER}_{\text{exist}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1000} \right]$$

$$\Delta \text{kWh Savings}_{\text{heat}} = \left[\frac{\text{EFLH}_{\text{Heat}} * \text{Capacity}_{\text{Heat}} * \left(\frac{1}{\text{COP}_{\text{exist}}} - \frac{1}{\text{COP}_{\text{ee}}} \right)}{3412} \right]$$

$$\Delta \text{kWh for remaining measure life (next 10 years)} = \text{Annual kWh Savings}_{\text{Cool}} + \text{Annual kWh Savings}_{\text{Heat}}$$

$$\Delta \text{kWh Savings}_{\text{cool}} = \left[\frac{\text{EFLH}_{\text{cool}} * \text{Capacity}_{\text{Cool}} * \left(\frac{1}{\text{EER}_{\text{base}}} - \frac{1}{\text{EER}_{\text{ee}}} \right)}{1000} \right]$$

²¹⁷ 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)

$$\Delta kWh Savings_{heat} = \left[\frac{EFLH_{Heat} * Capacity_{Heat} * \left(\frac{1}{COP_{base}} - \frac{1}{COP_{ee}} \right)}{3412} \right]$$

Where:

- EFLH_{cool} = Equivalent Full Load Hours for cooling are provided in section 3.3 HVAC End Use.
- Capacity_{Cool} = Cooling 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 8.1 EER²¹⁸
- EFLH_{heat} = heating mode equivalent full load hours are provided in section 3.3 HVAC End Use.
- Capacity_{Heat} = Heating 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 1.0 COP for PTAC units and 2.6 COP²¹⁹ for PTHPs.
- 3,412 = kBtu per kWh.

Copy of Table C403.2.3(3), IECC 2012: Minimum Efficiency Requirements: Electrically operated packaged terminal air conditioners, packaged terminal heat pumps

Equipment Type	Minimum Efficiency as of 10/08/2012
PTAC (Cooling mode) New Construction	13.8 – (0.300 x Cap/1000) EER
PTAC (Cooling mode) Replacements	10.9 – (0.213 x Cap/1000) EER
PTHP (Cooling mode) New Construction	14.0 – (0.300 x Cap/1000) EER
PTHP (Cooling mode) Replacements	10.8 – (0.213 x Cap/1000) EER
PTHP (Heating mode) New Construction	3.2 – (0.026 x Cap/1000) COP
PTHP (Heating mode) Replacements	2.9 – (0.026 x Cap/1000) 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.

Replacement unit shall be factory labeled as follows “MANUFACTURED FOR REPLACEMENT APPLICATIONS

²¹⁸ Estimated using the IECC building energy code up until year 2003 (p107; <https://law.resource.org/pub/us/code/ibr/icc.iecc.2000.pdf>) and assuming a 1 ton unit; EER = 10 – (0.16 * 12,000/1,000) = 8.1.

²¹⁹ Estimated using the IECC building energy code up until year 2003 (p107; <https://law.resource.org/pub/us/code/ibr/icc.iecc.2000.pdf>) and assuming a 1 ton unit; COP = 2.9 – (0.026 * 12,000/1,000) = 2.6

ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS”, Replacement efficiencies apply 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 new construction baseline):

For example a 1 ton PTAC with an efficient EER of 12 at a hotel in Burlington saves:

$$= [(12,000) * [(1/10.2) - (1/12)] / 1000 * 1,503$$

$$= 265 \text{ kWh}$$

Early Replacement (assuming replacement baseline for deferred replacement in 5 years):

For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 at a restaurant in Des Moines replaces a PTAC unit (with electric resistance heat) with unknown efficiency.

Δ kWh for remaining life of existing unit (1st 5years)

$$= (12,000 * (1/8.1 - 1/12) * 1,176) / 1,000 + (12,000/3,412 * (1/1.0 - 1/3.0) * 1,247)$$

$$= 566 + 2,924$$

$$= 3,490 \text{ kWh}$$

Δ kWh for remaining measure life (next 10 years)

$$= (12,000 * (1/8.3 - 1/12) * 1,176) / 1,000 + (12,000/3,412 * (1/1.0 - 1/3.0) * 1,247)$$

$$= 524 + 2,924$$

$$= 3,448 \text{ kWh}$$

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:

Δ kW for remaining life of existing unit (1st 5years):

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{EER_{exist}} - \frac{1}{EER_{ee}} \right)}{1000} \right] * CF$$

Δ kWh for remaining measure life (next 10 years):

$$\Delta kW = \left[\frac{Capacity_{Cool} * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right)}{1000} \right] * CF$$

Where:

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.3.8 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

Building Type	CF ²²⁰
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ²²¹	79.8%

Time of Sale:

For example a 1 ton PTAC with an efficient EER of 12 at a hotel in Burlington saves:

$$\Delta kW = (12,000 * (1/10.2 - 1/12) / 1,000 * 0.888 = 0.16 \text{ kW}$$

Early Replacement (assuming replacement baseline for deferred replacement in 5 years):

For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 at a restaurant in Des Moines replaces a PTAC unit (with electric resistance heat) with unknown efficiency.

ΔkW for remaining life of existing unit (1st 5 years):

$$\Delta kW = 12,000 * (1/8.1 - 1/12) / 1,000 * 0.888 = 0.43 \text{ kW}$$

ΔkW for remaining measure life (next 10 years):

$$\Delta kW = 12,000 * (1/8.3 - 1/12) / 1,000 * 0.888 = 0.39 \text{ kW}$$

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

²²⁰ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

²²¹ 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)

MEASURE CODE: NR-HVC-PTAC-V01-170101

SUNSET DATE: 1/1/2020

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 years²²².

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 GREM²²³.

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

²²² DEER 2008 value for energy management systems

²²³ This value was extracted from Smart Ideas projects in PY1 and PY2.

Algorithm

CALCULATION OF SAVINGS

Below are the annual kWh savings per installed energy management system for different climate zones. The savings 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 simulation²²⁴. 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 kWh Savings [kWh/room/year]	Cooling kWh Savings [kWh/room/year]	Lighting Savings [kWh/room/year]
Des Moines	135.8	22.2	62.0
Burlington	111.3	24.6	62.0
Mason City	151.5	17.8	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,
= 88.8% (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 ²²⁵ [therms/room/year]
Des Moines	5.8
Burlington	4.7

²²⁴ 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.

²²⁵ Savings include the assumption that the thermal efficiency of the heating unit is 80%, per IECC2012 code.

Climate Zone	Gas Savings ²²⁵ [therms/room/year]
Mason City	6.5

PEAK GAS SAVINGS

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

Where:

- $\Delta Therms$ = Therm impact calculated above
- GCF = Gas Coincidence Factor for Heating
=0.011829for Lodging

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-GREM-V01-170101

SUNSET DATE: 1/1/2020

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 measure²²⁶
= Actual
- 100,000 = Converts Btu to therms

For a 200 kBtu boiler in a Des Moines small office that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta therms &= (200,000 * 1495 * (((0.82 + 0.018)/ 0.82) - 1)) / 100,000 \\ &= 65.6 \text{ therms} \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

- $\Delta Therms$ = Therm impact calculated above

²²⁶ 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.

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ²²⁷
Convenience	0.016310
Education	0.013261
Grocery	0.021811
Health	0.011071
Hospital	0.013578
Industrial	0.014240
Lodging	0.008752
Multifamily	0.008752
Office - Large	0.010094
Office - Small	0.011695
Religious	0.011745
Restaurant	0.010510
Retail - Large	0.014243
Retail - Small	0.011861
Warehouse	0.012010
Nonresidential Average ²²⁸	0.012000

For a 200 kBtu boiler in a Des Moines small office that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\Delta\text{PeakTherms} = 65.6 * 0.011695$$

$$= 0.7672 \text{ therms}$$

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-V01-170101

SUNSET DATE: 1/1/2023

²²⁷ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

²²⁸ 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 12 months²²⁹.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life of a clean and check tune-up is 1 year.

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune-up.

LOADSHAPE

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

Loadshape NREH01:16 – Nonresidential Electric Heating (by Building Type)

²²⁹ 2014 IPL Savings Reference Manual, July 21, 2014

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta Therms * Fe * 29.3$$

Where:

- $\Delta Therms$ = as calculated below
- F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
= 3.14%²³⁰
- 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:

- Eff_{before} = Combustion Efficiency of the furnace before the tune-up
= Actual
- E_i = Combustion Efficiency Improvement of the furnace tune-up measure²³¹
= Actual

For a 200 kBtu furnace in a Des Moines small office that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta therms &= (200,000 * 1495 * (((0.82 + 0.018)/ 0.82) - 1)) / 100,000 \\ &= 65.6 therms \end{aligned}$$

PEAK GAS SAVINGS

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

Where:

- $\Delta Therms$ = Therm impact calculated above
- GCF = Gas Coincidence Factor for Heating

²³⁰ 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.

²³¹ 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.

Building Type	GCF ²³²
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ²³³	0.012386

For a 200 kBtu furnace in a Des Moines small office that records an efficiency prior to tune-up of 82% AFUE and a 1.8% improvement in efficiency after tune-up:

$$\begin{aligned} \Delta\text{PeakTherms} &= 65.6 * 0.011789 \\ &= 0.7734 \text{ therms} \end{aligned}$$

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-V01-170101

SUNSET DATE: 1/1/2019

²³² Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

²³³ For weighting factors, see HVAC variable table in section 3.3.

3.3.12 Small Commercial Programmable Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses as defined by programs²³⁴, 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 (TBD). 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: 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 programmable thermostat is assumed to be 8 years²³⁵ based upon equipment life only²³⁶. For the purposes of claiming savings for a new programmable thermostat, this is reduced by a 50% persistence factor to give a final measure life of 4 years.

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 \$181²³⁷.

LOADSHAPE

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

²³⁴ The square footage of the small office prototype building modeled in eQuest is 7,500 sf.

²³⁵ Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

²³⁶ Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer term impacts should be assessed.

²³⁷ 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

$$\Delta kWh = \frac{Sqft * Savings\ Factor}{EfficiencyRating(exist)}$$

Where:

- Sqft = square footage of building controlled by thermostat
- EfficiencyRating(exist) = efficiency rating of existing cooling equipment EER (btu hr/W)
- Savings Factor = 0.53 kBtu/sf-yr²³⁸

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{Sqft * Savings\ Factor * 100}{EfficiencyRating(exist)}$$

Where:

- Sqft = square footage of building controlled by thermostat
- EfficiencyRating(exist) = efficiency rating of existing heating equipment (AFUE)
- Savings Factor = 0.85 kBtu/sf-yr²³⁹

PEAK GAS SAVINGS

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

Where:

- ΔTherms = Therm impact calculated above
- GCF = Gas Coincidence Factor for Heating

Building Type	GCF ²⁴⁰
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352

²³⁸ 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.

²³⁹ 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.

²⁴⁰ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.3.12 Small Commercial Programmable Thermostats

Building Type	GCF ²⁴⁰
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ²⁴¹	0.012386

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-PROG-V01-170101

SUNSET DATE: 1/1/2018

²⁴¹ For weighting factors, see HVAC variable table in section 3.3.

3.3.13 Variable Frequency Drives for HVAC Pumps

DESCRIPTION

This measure applies to variable frequency drives (VFDs) installed on HVAC chilled water and hot water distribution pumps. There is a separate measure for HVAC supply and return fans. The VFD will modulate the speed of the motor when it does not need to run at full load. 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 pump motor 1-75 HP that does not have a VFD. The hydronic system that the VFD 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 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. 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 savings²⁴².

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.²⁴³

DEEMED MEASURE COST

Customer-provided costs will be used when available. Default measure costs are listed below for 1 to 75 HP motors²⁴⁴.

HP	Cost
1-9 HP	\$1,874
10-19 HP	\$2,967
20-29 HP	\$4,060
30-39 HP	\$5,154
40-49 HP	\$6,247
50-59 HP	\$7,340
60-69 HP	\$8,433
70-75 HP	\$9,526

LOADSHAPE

²⁴² 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”.

²⁴³ Efficiency Vermont TRM 3/16/2015 for HVAC VFD motors.

²⁴⁴ Average from IPL and MidAmerican VFD reported costs from rebate forms. IPL & MidA VFD Costs. xls

Loadshape NRE07 – VFD - Boiler feedwater pumps

Loadshape NRE08 – VFD - Chilled water pumps

Loadshape NRE09 – VFD - Boiler circulation pumps

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 determined²⁴⁵. 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 type²⁴⁶. When available, actual hours should be used.

Building Type	Hot Water Pump Hours	Chilled Water Pump Hours
Convenience	3628	2690
Education	3566	2833
Grocery	2551	3994
Health	3957	4369
Hospital	4260	4647
Industrial	3977	3080
Lodging	5287	5292
Multifamily	5287	5292
Office - Large	5864	4608
Office - Small	4482	2702
Religious	4763	2223
Restaurant	4127	2974
Retail - Large	4218	2405
Retail - Small	3985	2120
Warehouse	4100	1788
Nonresidential Average	4253	2331

²⁴⁵ 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.

²⁴⁶ ComEd TRM June 1, 2010 page 139. The Office hours is based upon occupancy from the eQuest model developed for EFLH..

ESF = Energy savings factor varies by VFD application. Units are kW/HP.

Application	ESF ²⁴⁷
Hot Water Pump	0.424
Chilled Water Pump	0.411

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{BHP}{EFFi} * DSF$$

Where:

DSF = Demand Savings Factor varies by VFD application.²⁴⁸ Units are kW/HP. Values listed below are based on typical peak load for the listed application.

Application	DSF
Hot Water Pump	0
Chilled Water Pump	0.299

NATURAL GAS ENERGY SAVINGS

There are no expected fossil fuel impacts for this measure²⁴⁹.

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-V01-170101

SUNSET DATE: 1/1/2018

²⁴⁷ 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

²⁴⁸ 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

²⁴⁹ 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. 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 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 (example: 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 savings²⁵⁰.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years;²⁵¹

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs²⁵² are listed below for up to 100 hp motors.

HP	Cost
1-9 HP	\$1,874
10-19 HP	\$2,967
20-29 HP	\$4,060
30-39 HP	\$5,154
40-49 HP	\$6,247
50-59 HP	\$7,340
60-69 HP	\$8,433
70-79 HP	\$9,526
80-89 HP	\$10,620
90-100 HP	\$11,713

²⁵⁰ 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”.

²⁵¹ Efficiency Vermont TRM 10/26/11 for HVAC VFD motors.

²⁵² Average from IPL and MidAmerican VFD reported costs from rebate forms. IPL & MidA VFD Costs. xls

LOADSHAPE

- Loadshape NRE04 – VFD - Supply fans
- Loadshape NRE05 – VFD - Return fans
- Loadshape NRE06 – VFD - Exhaust fans

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS²⁵³

$$kWh_{Base} = \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * RHRS_{Base} * \sum_{0\%}^{100\%} (\%FF * PLR_{Base})$$

$$kWh_{Retrofit} = \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * RHRS_{base} * \sum_{30\%}^{100\%} (\%FF * PLR_{Retrofit})$$

$$\Delta kWh_{fan} = kWh_{Base} - kWh_{Retrofit}$$

$$\Delta kWh_{total} = \Delta kWh_{fan} * (1 + IE_{energy})$$

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%)²⁵⁴
- η_{motor} = Installed nominal/nameplate motor efficiency
= Actual
- $RHRS_{Base}$ = Annual operating hours for fan motor based on building type
Default hours are provided for HVAC applications which vary by building type²⁵⁵. When available, actual hours should be used.

²⁵³ 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.

²⁵⁴ 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.

²⁵⁵ 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.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.3.14 Variable Frequency Drives for HVAC Supply and Return Fans

Building Type	Fan Run Hours
Convenience	4630
Education	1877
Grocery	4663
Health	3806
Hospital	6520
Industrial	2850
Lodging	3061
Multifamily	3061
Office - Large	2920
Office - Small	2920
Religious	2412
Restaurant	5443
Retail - Large	4065
Retail - Small	3694
Warehouse	2920
Nonresidential Average ²⁵⁶	3065

%FF = Percentage of run-time spent within a given flow fraction range²⁵⁷

Flow Fraction (% of design cfm)	Percent of Time at Flow Fraction
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							
	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
Discharge Dampers	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, BI & Airfoil Fans	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, BI & Airfoil Fans	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Inlet Vane Dampers	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Outlet Damper, FC Fans	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06

²⁵⁶ For weighting factors, see HVAC variable table in section 3.3.

²⁵⁷ 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							
	30%	40%	50%	60%	70%	80%	90%	100%
Eddy Current Drives	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane, FC Fans	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
VFD with duct static pressure controls	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01
VFD with low/no duct static pressure	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%)²⁵⁸

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$kW_{Base} = \left(0.74 * HP * \frac{LF}{\eta_{motor}} \right) * PLR_{Base,FFpeak}$$

$$kW_{Retrofit} = \left(0.746 * HP * \frac{LF}{\eta_{motor}} \right) * PLR_{Retrofit,FFpeak}$$

$$\Delta kW_{fan} = kW_{Base} - kW_{Retrofit}$$

$$\Delta kW_{total} = \Delta kW_{fan} * (1 + IE_{demand})$$

Where:

- kW_{Base} = Baseline summer coincident peak demand (kW)
- $kW_{Retrofit}$ = Retrofit summer coincident peak demand (kW)
- ΔkW_{fan} = Fan-only summer coincident peak demand impact
- ΔkW_{total} = Total project summer coincident peak demand impact
- $PLR_{Base,FFpeak}$ = 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%)

²⁵⁸ 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

$PLR_{\text{Retrofit,FFpeak}}$	= 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.²⁵⁹

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-V01-170101

SUNSET DATE: 1/1/2018

²⁵⁹ 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 insulating 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 that has been insulated.

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.²⁶⁰

DEEMED MEASURE COST

Per the 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”, the material cost for R-30 insulation is \$0.75 per square foot. The installation cost is \$0.61 per square foot. The total measure cost, therefore, is \$1.36 per square foot of insulation installed. However, the actual cost should be used when available.

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

²⁶⁰ Consistent with duct insulation measure life specified in the MidAmerican Energy Company Joint Assessment, February 2013.

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $R_{existing}$ = Duct heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
= Actual
- R_{new} = Duct heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
= Actual
- Area = Area of the duct surface exposed to the unconditioned space that has been insulated [ft²].
- $EFLH_{cooling}$ = 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 temperature²⁶¹

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ²⁶²	$\Delta T_{AVG,cooling}$ [°F]
Burlington	80.4	20.4
Des Moines	78.6	18.6
Mason City	75.2	15.2

- 1,000 = Conversion from Btu to kBtu
- $\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)
= Actual

If 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 temperature²⁶³

²⁶¹ 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.

²⁶² 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.

²⁶³ 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.

Climate Zone (City based upon)	OA _{AVG,heating} [°F] ²⁶⁴	ΔT _{AVG,heating} [°F]
Burlington	39.6	75.4
Des Moines	35.9	79.1
Mason City	30.1	84.9

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%*

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.
 Fe = Percentage of heating energy consumed by fans, assume 3.14%²⁶⁵
 29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh_{\text{cooling}}}{EFLH_{\text{cooling}}} * CF$$

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 ²⁶⁶
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%

²⁶⁴ 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.

²⁶⁵ 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.

²⁶⁶ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from eQuest models.

Building Type	CF ²⁶⁶
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ²⁶⁷	79.8%

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
= Actual

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 ²⁶⁸
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352

²⁶⁷ For weighting factors, see HVAC variable table in section 3.3.

²⁶⁸ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

Building Type	GCF ²⁶⁸
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ²⁶⁹	0.012386

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-DUCT-V01-170101

SUNSET DATE: 1/1/2022

²⁶⁹ For weighting factors, see HVAC variable table in section 3.3.

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 professionals²⁷⁰. 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.²⁷¹

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)

NREP01:16 – Nonresidential Electric Heat Pump (by Building Type)

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

²⁷⁰ 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.

²⁷¹ 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

= Actual²⁷²

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 temperature²⁷³

Climate Zone (City based upon)	OA _{AVG,cooling} [°F] ²⁷⁴	ΔT _{AVG,cooling} [°F]
Burlington	80.4	20.4
Des Moines	78.6	18.6
Mason City	75.2	15.2

0.018 = Specific Heat Capacity of Air (Btu/ft³*°F)

LM = Latent multiplier to account for latent cooling demand

= dependent on location: ²⁷⁵

²⁷² 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.

²⁷³ 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.

²⁷⁴ 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.

²⁷⁵ 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 5 (Burlington)	5.0
Zone 6 (Mason City)	5.9
Average/ unknown (Des Moines)	5.2

1000 = Converts Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/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 temperature²⁷⁶

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ²⁷⁷	$\Delta T_{AVG,heating}$ [°F]
Burlington	39.6	75.4
Des Moines	35.9	79.1
Mason City	30.1	84.9

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, a small retail building (2,000 Sq) Ft in Des Moines with 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{cooling} + \Delta kWh_{heating} \\ &= [((40 - 25) * 60 * 1039 * 18.6 * 0.018 * 5.2) / (1000 * 10.5)] + \\ &\quad [((40 - 25) * 60 * 1608 * 79.1 * 0.018) / (1.92 * 3,412)] \\ &= 155 + 314 \\ &= 469 kWh \end{aligned}$$

²⁷⁶ 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.

²⁷⁷ 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.

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * L_{Duct}$$

Where:

SavingsPerUnit = Annual savings per linear foot, dependent on heating / cooling equipment²⁷⁸

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 exterior ductwork sealed
 = 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

$$= 3.14\%^{279}$$

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:

$$\begin{aligned} \Delta kWh &= 17.9 * 0.0314 * 29.3 \\ &= 16.5 \text{ kWh} \end{aligned}$$

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

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

²⁷⁸ 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.

²⁷⁹ F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e. See "Furnace Fan Analysis.xlsx" for reference.

Building Type	CF ²⁸⁰
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ²⁸¹	79.8%

For example, a small retail building (2,000 Sq) Ft in Des Moines with 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), with pre- and post-sealing natural infiltration rates of 40 and 25 CFM, respectively:

$$\begin{aligned} \Delta kW &= 155 / 1039 * 0.877 \\ &= 0.13 \text{ kW} \end{aligned}$$

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, 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:

$$\begin{aligned} \Delta Therms &= ((40 - 25) * 60 * 1036 * 75.4 * 0.018) / (0.70 * 100,000) \\ &= 17.9 \text{ therms} \end{aligned}$$

Conservative Deemed Approach

$$\Delta Therms = SavingsPerUnit * L_{Duct}$$

Where:

²⁸⁰ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

²⁸¹ For weighting factors, see HVAC variable table in section 3.3.

SavingsPerUnit = Annual savings per linear foot, dependent on heating / cooling equipment²⁸²

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 ²⁸³
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ²⁸⁴	0.012386

²⁸² 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.

²⁸³ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

²⁸⁴ For weighting factors, see HVAC variable table in section 3.3.

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:

$$\begin{aligned}\Delta\text{PeakTherms} &= 17.9 * 0.013452 \\ &= 0.2408 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-HVC-DCTS-V01-170101

SUNSET DATE: 1/1/2022

3.3.17 Chiller Pipe Insulation

DESCRIPTION

Energy and demand saving are realized through reductions in the building cooling loads by insulating 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.²⁸⁵

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 Means²⁸⁶ pricing. 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

²⁸⁵ 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

²⁸⁶ RS Means 2008. Mechanical Cost Data, pages 106 to 119

The electric energy saved in annual cooling due to the added insulation is:

$$\Delta kWh_{cooling} = \frac{(L_{SP} + L_{OC}) * EFLH_{cooling} * (HG_{Base} - HG_{Eff})}{(1,000 * \eta_{cooling})}$$

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})

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 table²⁸⁷:

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

²⁸⁷ 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]
9	2.455
9.5	2.398
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

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 ²⁸⁸
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ²⁸⁹	79.8%

NATURAL GAS SAVINGS

N/A

²⁸⁸ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from eQuest models.

²⁸⁹ For weighting factors, see HVAC variable table in section 3.3.

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-V01-170101

SUNSET DATE: 1/1/2022

3.3.18 Hydronic Heating Pipe Insulation

DESCRIPTION

This measure provides rebates for installation of ≥ 1 " or ≥ 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.²⁹⁰

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.²⁹¹

DEEMED MEASURE COST

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means²⁹² pricing

²⁹⁰ ASHRAE Handbook—Fundamentals, 23.14; Hart, G., "Saving energy by insulating pipe components on steam and hot water distribution systems", *ASHRAE Journal*, October 2011

²⁹¹ 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

²⁹² RS Means 2008. Mechanical Cost Data, pages 106 to 119

reference materials may be used.²⁹³ The following table summarizes the estimated costs for this measure per foot 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 #	220719.10.0156	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

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})

Nominal Pipe Diameter	Equivalent Length of Other Components (ft)	
	90 Degree Elbow	Straight Tee
1”	0.30	0.38
2”	0.66	0.63

²⁹³ RS Means 2010: “for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting”

- 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 table²⁹⁴:

Pipe Location	System Type	Q _{base} - Q _{eff} (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:
- = 82% for a hot water boiler or 80% for a steam boiler ²⁹⁵
- 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 ²⁹⁶
- = See table below for base TRF values by pipe location
- May vary seasonally such as: TRF[summer] * summer hours + TRF[winter] * 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.²⁹⁷

²⁹⁴ 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.

²⁹⁵ 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.

²⁹⁶ 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.

²⁹⁷ Thermal Regain Factor_4-30-14.docx

Pipe Location	Assumed Regain	TRF, Thermal Regain Factor
Outdoor	0%	1.0
Indoor, heated space	85%	0.15
Indoor, semi- heated, (unconditioned space, with heat transfer to conditioned space. E.g.: boiler room, ceiling plenum, basement, crawlspace, wall)	30%	0.70
Indoor, unheated, (no heat transfer to conditioned space)	0%	1.0
Location not specified	85%	0.15
Custom	Custom	1 – assumed regain

PEAK GAS SAVINGS

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

Where:

$\Delta Therms$ = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ²⁹⁸
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ²⁹⁹	0.012386

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

²⁹⁸ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

²⁹⁹ For weighting factors, see HVAC variable table in section 3.3.

MEASURE CODE: NR-HVC-HPIN-V01-170101

SUNSET DATE: 1/1/2022

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.³⁰⁰

DEEMED MEASURE COST

The deemed measure cost for this approximately \$1,500.³⁰¹

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

³⁰⁰ 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.

³⁰¹ 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

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%³⁰²

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 ³⁰³
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ³⁰⁴	0.012386

³⁰² 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”,
http://www.seai.ie/Your_Business/Technology/Buildings/Steam_Systems_Technical_Guide.pdf.

³⁰³ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

³⁰⁴ For weighting factors, see HVAC variable table in section 3.3.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.3.19 Shut Off Damper for Space Heating Boilers or Furnaces

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The deemed annual Operations and Maintenance cost is \$112.³⁰⁵

MEASURE CODE: NR-HVC-SODP-V01-170101

SUNSET DATE: 1/1/2020

³⁰⁵ 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

DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets the ENERGY STAR minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:³⁰⁶

Product Class (Btu/H)	Federal Standard CEERbase, with louvered sides, without reverse cycle ³⁰⁷	Federal Standard CEERbase, without louvered sides, without reverse cycle	ENERGY STAR CEERee, with louvered sides	ENERGY STAR CEERee, without louvered sides
< 8,000	11.0	10.0	11.5	10.5
8,000 to 10,999	10.9	9.6	11.4	10.1
11,000 to 13,999		9.5		10.0
14,000 to 19,999	10.7	9.3	11.2	9.7
20,000 to 24,999	9.4	9.4	9.8	9.8
25,000-27,999	9.0		9.5	
>=28,000				

Casement	Federal Standard CEERbase	ENERGY STAR CEERee
Casement-only	9.5	10.0
Casement-slider	10.4	10.8

Reverse Cycle - Product Class (Btu/H)	Federal Standard CEERbase, with louvered sides	Federal Standard CEERbase, without louvered sides ³⁰⁸	ENERGY STAR CEERee, with louvered sides ³⁰⁹	ENERGY STAR CEERee, without louvered sides
< 14,000	N/A	9.3	N/A	9.7
>= 14,000	N/A	8.7	N/A	9.1
< 20,000	9.8	N/A	10.3	N/A
>= 20,000	9.3	N/A	9.7	N/A

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.

³⁰⁶ Side louvers that extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models. Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size. Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.

<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf> and http://www.cee1.org/resid/seha/rm-ac/rm-ac_specs.pdf

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

³⁰⁷ Federal standard air conditioner baselines. <https://ees.lbl.gov/product/room-air-conditioners>

³⁰⁸ Federal standard air conditioner baselines. <https://ees.lbl.gov/product/room-air-conditioners>.

³⁰⁹ EnergyStar version 4.0 Room Air Conditioner Program Requirements.

<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf>.

DEFINITION OF EFFICIENT EQUIPMENT

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 9 years.³¹⁰

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be \$50 for an ENERGY STAR unit.³¹¹

LOADSHAPE

Loadshapes NREC01-NREC16 dependent on building type.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{(FLH_{RoomAC} * Btu/H * (\frac{1}{CEER_{base}} - \frac{1}{CEER_{ee}}))}{1000}$$

Where:

FLH_{RoomAC} = Full Load Hours of room air conditioning unit³¹²

Building Type	Burlington		Des Moines		Mason City	
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH
Convenience	243	458	332	419	379	350
Education	300	328	403	290	464	221
Grocery	158	612	228	538	299	460
Health	317	362	438	330	474	278

³¹⁰ Energy Star Room Air Conditioner Savings Calculator, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=AC

³¹¹ Energy Star Room Air Conditioner Savings Calculator, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=AC

³¹² 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:

http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf) to FLH for Central Cooling for the same location (provided by AHRI:

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) is 31%. This ratio has been applied to the EFLH assumptions from Section 3.3 (eQuest modeling).

Building Type	Burlington		Des Moines		Mason City	
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH
Hospital	281	571	333	519	427	423
Industrial	263	367	367	330	395	265
Lodging	433	466	528	420	589	336
Multifamily	433	466	528	420	589	336
Office - Large	419	380	462	354	501	301
Office - Small	400	339	463	304	519	244
Religious	410	344	557	320	581	247
Restaurant	321	411	387	365	428	296
Retail - Large	277	375	404	334	432	267
Retail - Small	372	365	498	322	548	261
Warehouse	374	296	446	268	504	215
Nonresidential Average	371	337	464	303	513	241

- Btu/H = Size of unit
- = Actual. If unknown assume 8500 Btu/hr ³¹³
- CEERbase = Efficiency of baseline unit
- = As provided in tables above
- CEERee = Efficiency of ENERGY STAR unit
- = Actual. If unknown assume minimum qualifying standard as provided in tables above

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

$$\Delta kWh_{ENERGY STAR} = (433 * 8500 * (1/10.9 - 1/11.4)) / 1000$$

$$= 14.8 kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- CF = Summer Peak Coincidence Factor for measure
- = 0.3³¹⁴

³¹³ Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

³¹⁴ 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)

1.01 = Factor to convert CEER to EER (CEER includes standby and off power consumption³¹⁵)

Other variables as defined above

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in a convenience store in Burlington during system peak:

$$\begin{aligned} \Delta kW_{\text{ENERGY STAR}} &= (8500 * (1/10.9*1.01 - 1/11.4*1.01)) / 1000 * 0.3 \\ &= 0.0104 \text{ kW} \end{aligned}$$

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-RMAC-V01-170101

[C.pdf](#))

³¹⁵ 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'.

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

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

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed remaining useful life of the existing room air conditioning unit being retired is 3 years³¹⁶.

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 unit³¹⁷

³¹⁶ One third of assumed measure life for Room AC.

³¹⁷ 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:

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:

Building Type	Burlington		Des Moines		Mason City	
	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH	Heating EFLH	Cooling EFLH
Convenience	243	458	332	419	379	350
Education	300	328	403	290	464	221
Grocery	158	612	228	538	299	460
Health	317	362	438	330	474	278
Hospital	281	571	333	519	427	423
Industrial	263	367	367	330	395	265
Lodging	433	466	528	420	589	336
Multifamily	433	466	528	420	589	336
Office - Large	419	380	462	354	501	301
Office - Small	400	339	463	304	519	244
Religious	410	344	557	320	581	247
Restaurant	321	411	387	365	428	296
Retail - Large	277	375	404	334	432	267
Retail - Small	372	365	498	322	548	261
Warehouse	374	296	446	268	504	215
Nonresidential Average	371	337	464	303	513	241

BtuH = Average size of rebated unit. Use actual if available - if not, assume 8500³¹⁸

EERexist = Efficiency of recycled unit
 = Actual if recorded - If not, assume 9.8³¹⁹

%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% ³²⁰

CEERNewbase = Efficiency of baseline unit

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) is 31%. This ratio has been applied to the EFLH assumptions from Section 3.3 (eQuest modeling).

³¹⁸ Based on maximum capacity average from the RLW Report; “Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.”

³¹⁹ The Federal Minimum for the most common type of unit (8000 – 13999 Btuh with side vents) from 1990-2000 was 9.0 EER, from 2000-2014 it was 9.8 EER, and is currently (2015) 10.9 CEER. Retirement programs will see a large array of ages being retired, and the true EER of many will have been significantly degraded. We have selected 9.0 as a reasonable estimate of the average retired unit, given a 9 year expected measure life. This is supported by material on the ENERGY STAR website, which, if reverse-engineered, indicates that an EER of 9.16 is used for savings calculations for a 10-year old RAC. Another statement indicates that units that are at least 10 years old use 20% more energy than a new ES unit, which equates to: 10.9EER/1.2 = 9.1 EER; <http://www.energystar.gov/ia/products/recycle/documents/RoomAirConditionerTurn-InAndRecyclingPrograms.pdf>

³²⁰ 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.

1.01 $= 10.9^{321}$
 = Factor to convert EER to CEER (CEER includes standby and off power consumption)³²².

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

CF = Summer Peak Coincidence Factor for measure
 = 0.3³²³

Other variables as defined above

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-V01-170101

SUNSET DATE: 1/1/2023

³²¹ Minimum Federal Standard for capacity range and most popular class (Without reverse cycle, with louvered sides, and 8,000 to 13,999 Btu/h); http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

³²² 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'.

³²³ 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)

3.4 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 eQuest modeling performed by VEIC. The 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). For ease of review, the table is included here and referenced in each measure.

Building Type	HOU	WHFe ³²⁴	WHFd ³²⁵	CF ³²⁶	WHFh ³²⁷	IFTherms Eff = 80%	IFkWh (resistance) COP = 1	IFkWh (heat pump) COP = 2.3
Convenience	4630	1.14	1.31	100.0%	0.36	0.015	0.36	0.16
Education	1877	1.15	1.67	62.3%	0.43	0.018	0.43	0.19
Grocery	4663	1.14	1.22	100.0%	0.32	0.014	0.32	0.14
Health	3806	0.58	1.55	96.1%	1.1	0.047	1.1	0.48
Hospital	6520	1.24	1.53	100.0%	0.52	0.022	0.52	0.22
Industrial	2850	1.02	1.02	91.8%	0.37	0.016	0.37	0.16
Lodging	3061	0.84	1.15	19.8%	0.57	0.024	0.57	0.25
Multifamily	3061	0.84	1.15	19.8%	0.57	0.024	0.57	0.25
Office - Large	2920	1.13	1.24	48.4%	0.60	0.026	0.60	0.26
Office - Small	2920	1.15	1.45	63.6%	0.40	0.017	0.40	0.17
Religious	2412	1.12	1.32	66.0%	0.46	0.020	0.46	0.20
Restaurant	5443	1.16	1.39	96.7%	0.44	0.019	0.44	0.19
Retail - Large	4065	1.14	1.34	100.0%	0.43	0.018	0.43	0.19
Retail - Small	3694	1.12	1.39	100.0%	0.46	0.019	0.46	0.20
Warehouse	2920	1.09	1.43	61.8%	0.44	0.019	0.44	0.19
Nonresidential Average ³²⁸	3065	1.13	1.42	71.7%	0.43	0.018	0.43	0.19
Unconditioned building	As above	1.0	1.0	As above	0.000	0.000	0.000	0.000
Refrigerated Cases ³²⁹	As above	1.29	1.29	As above	0.000	0.000	0.000	0.000
Freezer Cases ³³⁰	As above	1.50	1.50	As above	0.000	0.000	0.000	0.000

³²⁴ Determined as the total building electrical savings divided by the lighting electrical savings. Note that all of the modeled buildings are both heated and cooled.

³²⁵ 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.

³²⁶ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

³²⁷ 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.

³²⁸ For weighting factors, see HVAC variable table in section 3.3.

³²⁹ 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.

³³⁰ 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

DESCRIPTION

An efficient ENERGY STAR qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb.

This characterization assumes that the CFL 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.

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 in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard. Furthermore, the Technical Advisory Committee approved assuming a blended baseline condition of EISA qualified incandescent/halogen, CFL and LED lamps. This assumption should be reviewed during each update cycle and when the net to gross impacts for this measure are determined.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore, the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020.

This measure was developed to be applicable to the following program types: TOS, DI, 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 high-efficiency equipment must be a standard general service ENERGY STAR qualified CFL based upon the v1.1 ENERGY STAR specification for lamps (http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf). Note a new ENERGY STAR specification v2.0 will become effective on 1/2/2017 (<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf>).

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 70% EISA qualified halogen or incandescent and 20% CFL and 5% LED³³¹.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life should be calculated by dividing the rated life of the bulb (10,000 hours³³²) by the run hours for the building type. For example, using the average nonresidential assumption of 3065 hours would give 3.3 years. The lifetime should be capped to the number of years until 2020 due to the EISA backstop provision.

DEEMED MEASURE COST

³³¹ As proposed and discussed by Iowa TRM Oversight Committee and Technical Advisory Committee.

³³² As per ENERGY STAR Lamp evaluation specification V1.1, ENERGY STAR bulbs will have a rated life of at least 10,000 hours.

The incremental capital cost assumption for all bulbs under 2,000 lumens is \$1.03³³³ (baseline cost of \$2.17³³⁴ and efficient cost of \$3.20).

For bulbs over 2,000 lumens, the assumed incremental capital cost is \$2.76³³⁵ (baseline cost of \$3.44³³⁶ and efficient cost of \$6.20).

For a Direct Install measure, actual program delivery costs should be used if available. If not, the full cost of \$3.20³³⁷ per <2000 lumen bulb or \$6.20 per ≥ 2,000 lumen bulb should be used, plus \$10 labor³³⁸ for a total measure cost of \$13.20 per <2,000 lumen bulb and \$16.20 per ≥ 2,000 lumen bulb.

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} = Actual (if retrofit measure) or based on lumens of CFL bulb installed and includes blend of incandescent/halogen³³⁹, CFL and LED by weightings provided in table below³⁴⁰. Note that when an IA net-to-gross (NTG) factor is determined for this measure, this blended baseline should be replaced with the Incandescent/Halogen baseline only..
- Watts_{EE} = Actual wattage of CFL purchased or installed - If unknown, assume the following defaults³⁴¹:

³³³ Incandescent/halogen and CFL assumptions based on incremental costs for 60W equivalent (dominant bulb) from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

³³⁴ Based on 70% Incandescent (\$1.40), 25% CFL (\$3.20) and 5% LED (\$7.87). LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

³³⁵ Based on high brightness lamps from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

³³⁶ Based on 70% Incandescent (\$1.60), 25% CFL (\$6.20) and 5% LED (\$15.39)

³³⁷ Based on 15W CFL, “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

³³⁸ Assumption based on 15 minutes (including portion of travel time) and \$40 per hour.

³³⁹ Incandescent/Halogen wattage is based upon the post first phase of EISA wattage and wattage bins consistent with ENERGY STAR, v1.1; http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

³⁴⁰ Weightings were determined through discussions with the Technical Advisory Committee. These are based upon review of Itron socket saturation and inventory data, in addition to review of multiple other data sources on the lighting market in other jurisdictions.

³⁴¹ Watts_{EE} defaults are based upon the average available ENERGY STAR product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR product currently available, Watts_{EE} is based upon the ENERGY STAR minimum luminous efficacy (55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts) for the mid-point of the lumen range. See calculation at “cerified-light-bulbs-2015-06-18.xlsx”. These assumptions should be reviewed regularly to ensure they represent the available product.

Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Watts ^{EE} CFL	LED	Watts ^{Base}	Delta Watts
		70%	25%	5%		
250	309	25	5.1	4.0	19.0	13.9
310	749	29	9.4	6.7	23.0	13.6
750	1,049	43	13.4	10.1	33.9	20.6
1,050	1,489	53	18.9	12.8	42.5	23.5
1,490	2,600	72	24.8	17.4	57.5	32.7
2,601	3,000	150	41.1	43.1	117.4	76.3
3,001	3,999	200	53.8	53.8	156.2	102.3
4,000	6,000	300	65.0	76.9	230.1	165.1

Hours = Average hours of use per year are provided in Lighting Reference Table in Section 3.4. If unknown, use the Nonresidential Average value.

WHFe = Waste heat factors for energy to account for cooling energy savings from efficient lighting are provided for each building type in Lighting Reference Table in Section 3.4 - If unknown, use the Nonresidential Average value

ISR = In Service Rate or the percentage of units that get installed
 =100%³⁴² 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) ³⁴³
Retail (Time of Sale) ³⁴⁴	95%
Direct Install ³⁴⁵ and Retrofit	97%

Heating Penalty:

If electrically heated building³⁴⁶:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

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

³⁴² Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

³⁴³ All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%), see "Non-Res Lighting ISR calculation.xlsx" for more information.

³⁴⁴ In service rate for Retail CFLs is based upon review of PY4-6 evaluations from ComEd's, Illinois commercial lighting program (BILD).

³⁴⁵ Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys; <http://www.ilsag.info/evaluation-documents.html>

³⁴⁶ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * WHFd * CF$$

Where:

- WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is 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)³⁴⁷:

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTherms)$$

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 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 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
= 197³⁴⁸

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The O&M assumptions that should be used in the cost effectiveness calculation are provided below. If unknown building type, assume Nonresidential Average:

³⁴⁷ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

³⁴⁸ Number of days where HDD 55 >0.

Building Type	Replacement Period (years) ³⁴⁹	Replacement Cost
Convenience	0.91	\$2.17 for bulbs <2,000 lumens \$3.44 for bulbs ≥2,000 lumens
Education	2.24	
Grocery	0.90	
Health	1.10	
Hospital	0.64	
Industrial	1.47	
Lodging	1.37	
Multifamily	1.37	
Office - Large	1.44	
Office - Small	1.44	
Religious	1.74	
Restaurant	0.77	
Retail - Large	1.03	
Retail - Small	1.14	
Warehouse	1.44	
Nonresidential Average	1.37	

MEASURE CODE: NR-LTG-STCFL-VO1-170101

SUNSET DATE: 1/1/2018

³⁴⁹ Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC). Assumed lifetime of CFL is 10,000 and of LED is 20,000 hours. Values provided are an average based on 70% incandescent/halogen, 25% CFL and 5% LED (blended average of 4200 hours).

3.4.2 Compact Fluorescent Lamp - Specialty

DESCRIPTION

An ENERGY STAR qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb.

This characterization assumes that the CFL 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.

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

Energy Star qualified specialty CFL bulb based upon the v1.1 ENERGY STAR specification for lamps (http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf). Note a new ENERGY STAR specification v2.0 will become effective on 1/2/2017 (<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf>).

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 80% EISA qualified halogen or incandescent and 10% CFL and 10% LED³⁵⁰. Lamp types includes those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 ($\leq 40\text{We}$), candelabra base ($\leq 60\text{We}$), vibration service bulb, decorative candle with medium or intermediate base ($\leq 40\text{We}$), 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 $>40\text{We}$), candle (shapes B, BA, CA $>40\text{We}$), candelabra base lamps ($>60\text{We}$), and intermediate base lamps ($>40\text{We}$).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life should be calculated by dividing the rated life of the bulb (10,000 hours³⁵¹) by the run hours for the building type. For example, using the average Nonresidential assumption of 3065 hours would give 3.3 years.

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs³⁵²:

³⁵⁰ As proposed and discussed by Iowa TRM Oversight Committee and Technical Advisory Committee.

³⁵¹ As per ENERGY STAR Lamp evaluation specification V1.1, ENERGY STAR bulbs will have a rated life of at least 10,000 hours.

³⁵² Incandescent/halogen and CFL costs are based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year's worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; "Energy Savings Potential of Solid-State Lighting in General Illumination Applications", Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

Bulb Type	CFL Wattage	CFL	Incandescent	LED	Blended Baseline ³⁵³	Incremental Cost
Directional	< 20W	\$7.84	\$6.31	\$14.52	\$7.28	\$0.56
	≥20W	\$9.31		\$45.85	\$10.56	-\$1.25
Decorative and Globes	<15W	\$7.80	\$3.92	\$8.09	\$4.73	\$3.08
	≥15W	\$8.15		\$15.86	\$5.54	\$2.61

For other bulb types, or unknown, assume the incremental capital cost of \$1.81 (blended baseline cost of \$6.01 and efficient cost of \$7.82³⁵⁴).

For the Direct Install measure, the full CFL cost should be used plus \$10 labor³⁵⁵. However, actual program delivery costs should be used if available.

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} = Based on lumens of CFL bulb installed and includes blend of incandescent/halogen³⁵⁶, CFL and LED by weightings provided in table below³⁵⁷. Note that when an IA net-to-gross (NTG) factor is determined for this measure, this blended baseline should be replaced with the Incandescent/Halogen baseline only.

Watts_{EE} = Actual wattage of energy efficient specialty bulb purchased - If unknown, assume the following defaults³⁵⁸:

EISA exempt bulb types:

³⁵³ Assumes 80% Incandescent/halogen, 10% CFL and 10% LED.

³⁵⁴ Average of lower wattage bins.

³⁵⁵ Assumption based on 15 minutes (including portion of travel time) and \$40 per hour.

³⁵⁶ 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.

³⁵⁷ Weightings were determined through discussions with the Technical Advisory Committee. These are based upon review of Itron socket saturation and inventory data, in addition to review of multiple other data sources on the lighting market in other jurisdictions.

³⁵⁸ Watts_{EE} defaults are based upon the average available ENERGY STAR product, accessed 06/18/2015. For any lamp type / lumen range where there is no ENERGY STAR product currently available, Watts_{EE} is based upon the ENERGY STAR minimum luminous efficacy (Omnidirectional; 55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts, Directional; 40Lm/W for lamps with rated wattages less than 20W and 50 Lm/W for lamps with rated wattages ≥ 20 watts and Decorative; 45Lm/W for lamps with rated wattages less than 15W, 50Lm/W for lamps ≥15 and <25W, 60 Lm/W for ≥ 25 watts) for the mid-point of the lumen range. See calculation at “cerified-light-bulbs-2015-06-18.xlsx” . These assumptions should be reviewed regularly to ensure they represent the available product.

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Watts ^{EE} CFL	LED	Watts ^{Base}	Delta Watts CFL
				80%	10%	10%		
EISA Exempt	3-Way	250	449	25	6.4	6.4	21.3	14.9
		450	799	40	11.4	11.4	34.3	22.9
		800	1,099	60	13.0	10.0	50.3	37.3
		1,100	1,599	75	20.8	13.1	63.4	42.6
		1,600	1,999	100	26.0	19.4	84.5	58.6
		2,000	2,549	125	32.2	35.0	106.7	74.5
		2,550	2,999	150	40.0	42.7	128.3	88.3
	Globe (medium and intermediate bases less than 750 lumens)	90	179	10	3.0	3.0	8.6	5.6
		180	249	15	4.8	4.8	13.0	8.2
		250	349	25	6.7	4.1	21.1	14.4
		350	749	40	9.9	6.5	33.6	23.7
	Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10	1.8	1.8	8.4	6.6
		90	149	15	2.7	2.7	12.5	9.9
		150	299	25	5.0	3.7	20.9	15.9
		300	749	40	7.5	5.3	33.3	25.7
	Globe (candelabra bases less than 1050 lumens)	90	179	10	3.0	3.0	8.6	5.6
		180	249	15	4.8	4.8	13.0	8.2
		250	349	25	6.7	4.1	21.1	14.4
		350	499	40	9.4	4.8	33.4	24.0
		500	1,049	60	15.5	7.0	50.2	34.8
	Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10	1.8	1.8	8.4	6.6
		90	149	15	2.7	2.7	12.5	9.9
		150	299	25	5.0	3.0	20.8	15.8
		300	499	40	7.7	4.7	33.2	25.6
		500	1,049	60	15.5	6.9	50.2	34.7

Directional Lamps - For Directional R, BR, and ER lamp types³⁵⁹:

³⁵⁹ From pg 11 of the Energy Star Specification for lamps v1.1.

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Watts ^{EE} CFL	LED	Watts ^{Base}	Delta Watts CFL
				80%	10%	10%		
Directional	R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40	11.0	7.5	33.9	22.9
		473	524	45	12.5	7.9	38.0	25.6
		525	714	50	14.9	9.1	42.4	27.5
		715	937	65	15.6	12.6	54.8	39.2
		938	1,259	75	21.1	16.1	63.7	42.6
		1,260	1,399	90	23.0	17.8	76.1	53.1
		1,400	1,739	100	31.4	19.2	85.1	53.7
		1,740	2,174	120	39.1	25.6	102.5	63.3
		2,175	2,624	150	48.0	28.8	127.7	79.7
		2,625	2,999	175	56.2	56.2	151.2	95.0
	3,000	4,500	200	75.0	75.0	175.0	100.0	
	*R, BR, and ER with medium screw bases w/ diameter ≤2.25"	400	449	40	10.6	6.3	33.7	23.1
		450	499	45	11.9	6.8	37.9	26.0
		500	649	50	14.4	7.3	42.2	27.8
		650	1,199	65	18.5	13.3	55.2	36.7
	*ER30, BR30, BR40, or ER40	400	449	40	10.6	10.6	34.1	23.5
		450	499	45	11.9	11.9	38.4	26.5
		500	649	50	14.4	12.0	42.6	28.3
	*BR30, BR40, or ER40	650	1,419	65	18.0	12.4	55.0	37.1
	*R20	400	449	40	10.6	10.6	34.1	23.5
		450	719	45	12.5	7.7	38.0	25.5
	*All reflector lamps below lumen ranges specified above	200	299	20	6.2	4.0	17.0	10.8
		300	399	30	8.7	6.2	25.5	16.8

Directional lamps are exempt from EISA regulations

EISA non-exempt bulb types:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Watts ^{EE} CFL	LED	Watts ^{Base}	Delta Watts CFL
				80%	10%	10%		
EISA Non-Exempt	Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	250	309	25	5.1	4.1	20.9	15.8
		310	749	29	9.5	6.6	24.8	15.3
		750	1049	43	13.5	10.1	36.8	23.3
		1050	1489	53	18.9	12.8	45.6	26.6
		1490	2600	72	24.8	17.4	61.8	37.0

ISR = In Service Rate or the percentage of units rebated that get installed
 =100%³⁶⁰ if application form completed with sign off that equipment is not placed into storage. If sign off form not completed, assume the following:

³⁶⁰ Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

Program	Discounted In Service Rate (ISR) ³⁶¹
Retail (Time of Sale) ³⁶²	95%
Direct Install ³⁶³ and Retrofit	97%

Hours = Average hours of use per year are provided in the Lighting Reference Table in Section 3.4 - If unknown, use the Nonresidential Average value

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Lighting Reference Table in Section 3.4 - If unknown, use the Nonresidential Average value

Heating Penalty:

If electrically heated building³⁶⁴:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

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

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * WHFd * CF$$

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 SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown)³⁶⁵:

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTtherms)$$

Where:

³⁶¹ All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%); see “Non-Res Lighting ISR calculation.xlsx” for more information.

³⁶² In service rate for Retail CFLs is based upon review of PY4-6 evaluations from ComEd’s, Illinois commercial lighting program (BILD).

³⁶³ Based upon review of the Illinois PY2 and PY3 ComEd Direct Install program surveys; <http://www.ilsag.info/evaluation-documents.html>

³⁶⁴ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

³⁶⁵ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

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 - 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

= 197³⁶⁶

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The O&M assumptions that should be used in the cost effectiveness calculation are provided below. If unknown, building type assume Nonresidential Average:

Building Type	Replacement Period (years)			Replacement Cost ³⁷⁰
	Directional ³⁶⁷	Decorative/Globe ³⁶⁸	Unknown ³⁶⁹	
Convenience	0.93	0.71	0.82	Directional: \$7.28 for < 20W, \$10.56 for ≥20W
Education	2.29	1.76	2.02	
Grocery	0.92	0.71	0.81	
Health	1.13	0.87	1.00	
Hospital	0.66	0.51	0.58	Decorative/Globe: \$4.73 for <15W, \$5.54 for ≥15W
Industrial	1.51	1.16	1.33	
Lodging	1.40	1.08	1.24	
Multifamily	1.40	1.08	1.24	
Office - Large	1.47	1.13	1.30	Unknown: \$6.01

³⁶⁶ Number of days where HDD 55 >0.

³⁶⁷ Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC). Assumed lifetime of CFL is 10,000 and of LED is 25,000 hours. Values provided are an average based on 80% incandescent/halogen, 10% CFL and 10% LED (blended average of 4300 hours).

³⁶⁸ Assumed rated life of incandescent/halogen is 1000 hours, CFL is 10,000 and decorative LED is 15,000 hours. Values provided are an average based on 80% incandescent/halogen, 10% CFL and 10% LED (blended average of 3300 hours).

³⁶⁹ Values provided are an average of directional and decorative (blended average of 3800 hours).

³⁷⁰ Incandescen/halogen and CFL costs based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle. Baseline based on 80% Incandescent/halogen, 10% CFL and 10% LED.

Building Type	Replacement Period (years)			Replacement Cost ³⁷⁰
	Directional ³⁶⁷	Decorative/Globe ³⁶⁸	Unknown ³⁶⁹	
Office - Small	1.47	1.13	1.30	
Religious	1.78	1.37	1.58	
Restaurant	0.79	0.61	0.70	
Retail - Large	1.06	0.81	0.93	
Retail - Small	1.16	0.89	1.03	
Warehouse	1.47	1.13	1.30	
Nonresidential Average	1.40	1.08	1.24	

MEASURE CODE: NR-LTG-SPCFL-VO1-170101

SUNSET DATE: 1/1/2018

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 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.

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 v1.1 ENERGY STAR specification for lamps (http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf). Note a new ENERGY STAR specification v2.0 will become effective on 1/2/2017 (<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf>). Qualification could also be based on the Design Light Consortium's qualified product list³⁷¹.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 70% EISA qualified halogen or incandescent and 20% CFL and 5%LED³⁷². From 2020, the baseline becomes a CFL³⁷³, and therefore a midlife adjustment is provided.

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 20000.³⁷⁴

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume \$5.70 for <15W LED lamps

³⁷¹ <https://www.designlights.org/QPL>

³⁷² As proposed and discussed by the Iowa TRM Oversight Committee on 7/29/2015.

³⁷³ A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL.

³⁷⁴ Version 1.1 of the ENERGY STAR specification required omnidirectional bulbs have a rated life of 25,000 hours or more. Version 2.0 of the specification now only requires 15,000 hours. While the V2.0 is not effective until 1/2/2017, lamps may today be qualified with this updated rated life specification. In the absence of data suggesting an average – an assumed average rated life of 20,000 hours is used.

(baseline cost of \$2.17³⁷⁵ and efficient cost of \$7.87) and \$11.95 for ≥ 15W LED lamps (baseline cost of \$3.44³⁷⁶ and efficient cost of \$15.39)³⁷⁷.

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} = Based on lumens of LED bulb installed as and includes blend of incandescent/halogen³⁷⁸, CFL and LED by weightings provided in table below³⁷⁹. 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 .

Lower Lumen Range	Upper Lumen Range	Inc/Halogen	CFL	Watts _{EE} LED	Watts _{Base}	Delta Watts
		70%	25%	5%		
250	309	25	5.1	4.0	19.0	15.0
310	749	29	9.4	6.7	23.0	16.3
750	1,049	43	13.4	10.1	33.9	23.8
1,050	1,489	53	18.9	12.8	42.5	29.7
1,490	2,600	72	24.8	17.4	57.5	40.1
2,601	3,000	150	41.1	43.1	117.4	74.3

³⁷⁵ Based on 70% Incandescent (\$1.40), 25% CFL (\$3.20) and 5% LED (\$7.87)

³⁷⁶ Based on 70% Incandescent (\$1.60), 25% CFL (\$6.20) and 5% LED (\$15.39)

³⁷⁷ Incandescen/halogen and CFL costs based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

³⁷⁸ Incandescent/Halogen wattage is based upon the post first phase of EISA wattage and wattage bins consistent with ENERGY STAR, v1.1; http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

³⁷⁹ Weightings were determined through discussions with the Technical Advisory Committee. These are based upon review of Itron socket saturation and inventory data, in addition to review of multiple other data sources on the lighting market in other jurisdictions.

³⁸⁰ Watts_{EE} defaults are based upon the average available ENERGY STAR product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR product currently available, Watts_{EE} is based upon the ENERGY STAR minimum luminous efficacy (55Lm/W for lamps with rated wattages less than 15W and 65 Lm/W for lamps with rated wattages ≥ 15 watts) for the mid-point of the lumen range. See calculation at “cerified-light-bulbs-2015-06-18.xlsx”. These assumptions should be reviewed regularly to ensure they represent the available product.

Lower Lumen Range	Upper Lumen Range	Inc/Halogen	CFL	Watts ^{EE} LED	Watts ^{Base}	Delta Watts
		70%	25%	5%		
3,001	3,999	200	53.8	53.8	156.2	102.3
4,000	6,000	300	65.0	76.9	230.1	153.2

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) ³⁸¹
Retail (Time of Sale) ³⁸²	95%
Direct Install ³⁸³ and Retrofit	97%

Mid-Life Baseline Adjustment

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes to a CFL equivalent in 2020 due to the EISA backdrop provision (except for <310 and 2600+ lumen lamps), the annual savings claim must be reduced within the life of the measure to account for this baseline shift. This reduced annual savings will need to be incorporated in to cost effectiveness screening calculations. The baseline adjustment also impacts the O&M schedule.

For example, for 43W equivalent LED lamp installed in 2016, the full savings (as calculated above in the Algorithm) should be claimed for the first four years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) should be claimed for the remainder of the measure life. ³⁸⁴

Lower Lumen Range	Upper Lumen Range	Mid Lumen Range	Watts ^{EE}	Watts ^{Base} before EISA 2020	Delta Watts before EISA 2020	Watts ^{Base} after EISA 2020 ³⁸⁵	Delta Watts after EISA 2020	Mid Life adjustment (in 2020) to first year savings
250	309	280	4.0	19.0	15.0	19.0	15.0	100.0%
310	749	530	6.7	23.0	16.3	9.3	2.6	16.1%
750	1049	900	10.1	33.9	23.8	13.2	3.1	12.9%

³⁸¹ All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%), see “Non-Res Lighting ISR calculation.xlsx” for more information.

³⁸² Consistent with CFL assumption. In service rate for Retail CFLs is based upon review of PY4-6 evaluations from ComEd’s, Illinois commercial lighting program (BILD).

³⁸³ 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>

³⁸⁴ These adjustments should be applied to kW and gas impacts as well.

³⁸⁵ Calculated with EISA requirement of 45lumens/watt.

Lower Lumen Range	Upper Lumen Range	Mid Lumen Range	WattsEE	WattsBase before EISA 2020	Delta Watts before EISA 2020	WattsBase after EISA 2020 ³⁸⁵	Delta Watts after EISA 2020	Mid Life adjustment (in 2020) to first year savings
1050	1489	1270	12.8	42.5	29.7	18.6	5.8	19.7%
1490	2600	2045	17.4	57.5	40.1	24.4	7.0	17.6%
2,550	3,000	2,775	43.1	117.4	74.3	117.4	74.3	100.0%
3,001	3,999	3,500	53.8	156.2	102.3	156.2	102.3	100.0%
4,000	6,000	5,000	76.9	230.1	153.2	230.1	153.2	100.0%

Heating Penalty:

If electrically heated building³⁸⁶:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

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) ³⁸⁷:

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTtherms)$$

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. If unknown, use the Nonresidential Average value.

PEAK GAS SAVINGS

³⁸⁶ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

³⁸⁷ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

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
= 197³⁸⁸

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

In order to account for the falling EISA Qualified backdrop provision, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below³⁸⁹:

Lumen Range	70% EISA Compliant Incandescent / Halogen, 25% CFL, 5% LED	CFL	LED A-Lamp
<2,000	\$2.17	\$3.20	\$7.87
≥2,000	\$3.44	\$6.20	\$15.39

The present value for replacement lamps and annual levelized replacement costs using the statewide real discount rate of 7.71% are presented below³⁹⁰:

Lumen Range	Location	PV of replacement costs for period			Levelized annual replacement cost savings		
		2016 - 2017	2017 - 2018	2018 - 2019	2016 - 2017	2017 - 2018	2018 - 2019
310 - 2,000	Nonresidential Average	\$9.79	\$9.30	\$8.78	\$1.12	\$1.07	\$1.01
2,000 - 2600	Nonresidential Average	\$9.12	\$7.90	\$6.58	\$1.55	\$1.34	\$1.12

Note: incandescent lamps in lumen range <310 and >2600 are exempt from EISA. For these bulb types, an O&M cost should be applied as follows. If unknown building type, assume Nonresidential Average:

³⁸⁸ Number of days where HDD 55 >0.

³⁸⁹ Incandescen/halogen and CFL costs based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

³⁹⁰ See “C&I LED O&M.xls” for more information. The values assume the non-residential average hours assumption of 3065.

Building Type	Replacement Period (years) ³⁹¹	Replacement Cost ³⁹²
Convenience	0.9	\$2.17 for bulbs <2,000 lumens \$3.44 for bulbs ≥2,000 lumens
Education	2.2	
Grocery	0.9	
Health	1.1	
Hospital	0.6	
Industrial	1.5	
Lodging	1.4	
Multifamily	1.4	
Office - Large	1.4	
Office - Small	1.4	
Religious	1.7	
Restaurant	0.8	
Retail - Large	1.0	
Retail - Small	1.1	
Warehouse	1.4	
Nonresidential Average	1.4	

MEASURE CODE: NR-LTG-LEDA-VO1-170101

SUNSET DATE: 1/1/2018

³⁹¹ Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/Incandescents is 1000 hours (manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC)). Assumed lifetime of CFL is 10,000 and of LED is 20,000 hours. Values provided are an average based on 70% incandescent/halogen, 25% CFL and 5% LED (blended average of 4200 hours).

³⁹² Incandescen/halogen and CFL costs based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle. Baseline based on 70% Incandescent/halogen, 25% CFL and 5% LED.

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.

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 v1.1 ENERGY STAR specification for lamps (http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf). Note a new ENERGY STAR specification v2.0 will become effective on 1/2/2017 (<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf>). Qualification could also be based on the Design Light Consortium's qualified product list³⁹³.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be a blend of 80% EISA qualified halogen or incandescent and 10% CFL and 10% LED³⁹⁴. 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).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The ENERGY STAR rated life requirement for directional bulbs is 25,000 or more hours and for decorative bulbs is 15,000 hours³⁹⁵.

DEEMED MEASURE COST

³⁹³ <https://www.designlights.org/QPL>

³⁹⁴ As proposed and discussed by Iowa TRM Oversight Committee and Technical Advisory Committee.

³⁹⁵ ENERGY STAR, v1.1;

http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs³⁹⁶:

Bulb Type	LED Wattage	LED	Incandescent	CFL	Blended Baseline ³⁹⁷	Incremental Cost
Directional	< 20W	\$14.52	\$6.31	\$7.84	\$7.28	\$7.24
	≥20W	\$45.85		\$9.31	\$10.56	\$35.29
Decorative and Globe	<15W	\$8.09	\$3.92	\$7.80	\$4.73	\$3.37
	15 to <25W	\$15.86		\$8.15	\$5.54	\$10.32
	≥25W	\$15.86		\$8.15	\$5.54	\$10.32

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:

Watt_{SBase} = Based on lumens of LED bulb installed and includes blend of incandescent/halogen³⁹⁸, CFL and LED by weightings provided in table below³⁹⁹. 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.

Watt_{SEE} = Actual wattage of LED purchased/installed. If unknown, use default provided below⁴⁰⁰.

EISA exempt bulb types:

³⁹⁶ Incandescent/halogen and CFL costs based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. LED lamp costs are based on a 2014/2015 VEIC review of a year’s worth of LED sales through VEIC implemented programs. The retail cost was averaged and then DOE price projection trends (from Department of Energy, 2012; “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1) used to decrease the cost for a 2017 TRM assumption (see 2015 LED Sales Review.xls). LED costs are falling rapidly and should be reviewed in each update cycle.

³⁹⁷ Assumes 80% Incandescent/halogen, 10% CFL and 10% LED.

³⁹⁸ 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.

³⁹⁹ Weightings were determined through discussions with the Technical Advisory Committee. These are based upon review of Itron socket saturation and inventory data, in addition to review of multiple other data sources on the lighting market in other jurisdictions.

⁴⁰⁰ Watt_{SEE} defaults are based upon the average available ENERGY STAR product, accessed 06/18/2015. For any lumen range where there is no ENERGY STAR product currently available, Watt_{SEE} is based upon the ENERGY STAR minimum luminous efficacy (Directional; 40Lm/W for lamps with rated wattages less than 20W and 50 Lm/W for lamps with rated wattages ≥ 20 watts. Decorative and Globe; 45Lm/W for lamps with rated wattages less than 15W, 50lm/W for lamps ≥15 and <25W, 60 Lm/W for lamps with rated wattages ≥ 25 watts.) for the mid-point of the lumen range. See calculation at “cerified-light-bulbs-2015-06-18.xlsx”. These assumptions should be reviewed regularly to ensure they represent the available product.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.4.4 LED Lamp Specialty

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Watts ^{EE} CFL	Watts ^{EE} LED	Watts ^{Base}	Delta Watts LED
				80%	10%	10%		
EISA Exempt	3-Way	250	449	25	6.4	6.4	21.3	14.9
		450	799	40	11.4	11.4	34.3	22.9
		800	1,099	60	13.0	10.0	50.3	40.3
		1,100	1,599	75	20.8	13.1	63.4	50.3
		1,600	1,999	100	26.0	19.4	84.5	65.1
		2,000	2,549	125	32.2	35.0	106.7	71.7
		2,550	2,999	150	40.0	42.7	128.3	85.6
	Globe (medium and intermediate bases less than 750 lumens)	90	179	10	3.0	3.0	8.6	5.6
		180	249	15	4.8	4.8	13.0	8.2
		250	349	25	6.7	4.1	21.1	16.9
		350	749	40	9.9	6.5	33.6	27.1
	Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10	1.8	1.8	8.4	6.6
		90	149	15	2.7	2.7	12.5	9.9
		150	299	25	5.0	3.7	20.9	17.2
		300	749	40	7.5	5.3	33.3	28.0
	Globe (candelabra bases less than 1050 lumens)	90	179	10	3.0	3.0	8.6	5.6
		180	249	15	4.8	4.8	13.0	8.2
		250	349	25	6.7	4.1	21.1	16.9
		350	499	40	9.4	4.8	33.4	28.6
		500	1,049	60	15.5	7.0	50.2	43.2
	Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10	1.8	1.8	8.4	6.6
		90	149	15	2.7	2.7	12.5	9.9
		150	299	25	5.0	3.0	20.8	17.8
		300	499	40	7.7	4.7	33.2	28.6
		500	1,049	60	15.5	6.9	50.2	43.3

Directional Lamps - For Directional R, BR, and ER lamp types⁴⁰¹:

Bulb Type		Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Watts ^{EE} CFL	Watts ^{EE} LED	Watts ^{Base}	Delta Watts LED
				80%	10%	10%		
Directional	R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420	472	40	11.0	7.5	33.9	26.3
		473	524	45	12.5	7.9	38.0	30.1
		525	714	50	14.9	9.1	42.4	33.3
		715	937	65	15.6	12.6	54.8	42.2
		938	1,259	75	21.1	16.1	63.7	47.6
		1,260	1,399	90	23.0	17.8	76.1	58.3
		1,400	1,739	100	31.4	19.2	85.1	65.9
		1,740	2,174	120	39.1	25.6	102.5	76.9
		2,175	2,624	150	48.0	28.8	127.7	98.9
		2,625	2,999	175	56.2	56.2	151.2	95.0
		3,000	4,500	200	75.0	75.0	175.0	100.0
		*R, BR, and ER with medium screw bases w/ diameter ≤2.25"	400	449	40	10.6	6.3	33.7
	450		499	45	11.9	6.8	37.9	31.1
	500		649	50	14.4	7.3	42.2	34.8
	650		1,199	65	18.5	13.3	55.2	41.8

⁴⁰¹ From pg 11 of the Energy Star Specification for lamps v1.1.

Bulb Type	Lower Lumen Range	Upper Lumen Range	Inc/Halogen	Watts ^{EE} CFL	Watts ^{EE} LED	Watts ^{Base}	Delta Watts LED
			80%	10%	10%		
*ER30, BR30, BR40, or ER40	400	449	40	10.6	10.6	34.1	23.5
	450	499	45	11.9	11.9	38.4	26.5
	500	649	50	14.4	12.0	42.6	30.6
*BR30, BR40, or ER40	650	1,419	65	18.0	12.4	55.0	42.7
*R20	400	449	40	10.6	10.6	34.1	23.5
	450	719	45	12.5	7.7	38.0	30.3
*All reflector lamps below lumen ranges specified above	200	299	20	6.2	4.0	17.0	13.0
	300	399	30	8.7	6.2	25.5	19.3

Directional lamps are exempt from EISA regulations.

EISA non-exempt bulb types:

Bulb Type	Lower Lumen Range	Upper Lumen Range	Inc/Halogen	CFL	Watts ^{EE} LED	Watts ^{Base}	Delta Watts LED	
			80%	10%	10%			
EISA Non Exempt	Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens),	250	309	25	5.1	4.1	20.9	16.8
		310	749	29	9.5	6.6	24.8	18.2
		750	1049	43	13.5	10.1	36.8	26.6
		1050	1489	53	18.9	12.8	45.6	32.8
	Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)	1490	2600	72	24.8	17.4	61.8	44.4

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) ⁴⁰²
Retail (Time of Sale) ⁴⁰³	95%
Direct Install ⁴⁰⁴ and Retrofit	97%

Heating Penalty:

⁴⁰² All Programs except for Direct Install assume that some lamps are not installed in the first year but are later installed in years 2 and 3. To ease implementation, these future installs are discounted using the statewide real discount rate (7.71%), see "Non-Res Lighting ISR calculation.xlsx" for more information.

⁴⁰³ Consistent with CFL assumption. In service rate for Retail CFLs is based upon review of PY4-6 evaluations from ComEd's, Illinois commercial lighting program (BILD).

⁴⁰⁴ 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>

If electrically heated building⁴⁰⁵:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

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) ⁴⁰⁶:

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTherms)$$

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
= 197⁴⁰⁷

⁴⁰⁵ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁴⁰⁶ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁴⁰⁷ Number of days where HDD 55 >0.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

For these bulb types, an O&M cost should be applied as follows. If unknown building type, assume Nonresidential Average:

Bulb Type	Building Type	Replacement Period (years)	Replacement Cost ⁴⁰⁸
Directional	Convenience	0.9	\$7.28 for < 20W, \$10.56 for ≥20W
	Education	2.3	
	Grocery	0.9	
	Health	1.1	
	Hospital	0.7	
	Industrial	1.5	
	Lodging	1.4	
	Multifamily	1.4	
	Office - Large	1.5	
	Office - Small	1.5	
	Religious	1.8	
	Restaurant	0.8	
	Retail - Large	1.1	
	Retail - Small	1.2	
	Warehouse	1.5	
Nonresidential Average	1.4		
Decorative/Globe ⁴⁰⁹	Convenience	0.7	\$4.73 for <15W, \$5.54 for ≥15W
	Education	1.8	
	Grocery	0.7	
	Health	0.9	
	Hospital	0.5	
	Industrial	1.2	
	Lodging	1.1	
	Multifamily	1.1	
	Office - Large	1.1	
	Office - Small	1.1	
	Religious	1.4	
	Restaurant	0.6	
	Retail - Large	0.8	
	Retail - Small	0.9	
	Warehouse	1.1	
Nonresidential Average	1.1		

MEASURE CODE: NR-LTG-LEDS-VO1-170101

SUNSET DATE: 1/1/2018

⁴⁰⁸ Based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

⁴⁰⁹ Assumed rated life of incandescent/halogen is 1000 hours, CFL is 10,000 and decorative LED is 15,000 hours. Values provided are an average based on 80% incandescent/halogen, 10% CFL and 10% LED (blended average of 3300 hours).

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 be ENERGY STAR labeled or on the Design Light Consortium qualifying fixture list⁴¹⁰.

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 years⁴¹¹.

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:

WattS_{Base} = Input wattage of the existing or baseline system. Reference the “LED New and Baseline

⁴¹⁰ DesignLights Consortium Qualified Products List <http://www.designlights.org/qpl>

⁴¹¹ GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures.

Assumptions” table for default values.

Watt _{SEE}	= 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 ⁴¹² .

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 ⁴¹³ ; 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.
-------	--

Mid Life Adjustment:

A midlife savings adjustment should be applied to any measure with a blended T12:Standard T8 baseline. The adjustment should occur in 2020 to account for the baseline lamp replacement assumption changing from a blended 50/50 Standard T8/T12 to 100% Standard T8 by 2020⁴¹⁴. The savings adjustment is calculated as follows, and is provided in the Reference Table section:

$$\% Adjustment = \left(\frac{Watts_{T8base} - Watts_{EE}}{Watts_{Blended\ T8/T12\ Base} - Watts_{EE}} \right)$$

Where:

Watts _{T8Base}	= Input wattage of the existing system based on 100% T8 fixture; see reference table below.
Watts _{BlendedT8/T12}	= Input wattage of the existing system based on 50% T8 / 50% T12; see reference table below.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * WHFd * CF$$

⁴¹² Negotiated value during Iowa TRM Technical Advisory Committee call, 08/25/2015.

⁴¹³ Negative value because this is an increase in heating consumption due to the efficient lighting.

⁴¹⁴ As of July 1, 2010, a Federal mandate states that the magnetic ballasts used in many T12 fixtures can no longer be produced for commercial and industrial applications. However there have been many loopholes that have meant T12 lamps continue to hold a significant market share. It is expected that new mandates will close the loophole within the next few years. T12 lamps have an average life of 20,000 hours and if we assume they are operated on average for 4500 hours annually, this would mean a lamp would have to be replaced every 4.5 years. We therefore assume that by 2020 all replacement lamps are Standard T8s. Therefore while the more likely scenario would be a gradual shift of the 50/50 weighted baseline to T8s over the timeframe, to simplify this assumption, a single midlife adjustment in 2020 is assumed.

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 impacts⁴¹⁵; 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 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
= 197⁴¹⁶

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

See Reference Tables below for default assumptions.

REFERENCE TABLES⁴¹⁷

⁴¹⁵ Negative value because this is an increase in heating consumption due to the efficient lighting.

⁴¹⁶ Number of days where HDD 55 >0.

⁴¹⁷ Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting 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. Efficient cost data comes from 2012 DOE “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1. See " Updated-LED Lighting Systems TRM Reference Tables7-30-15.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 (2020)
	Description	Watt _{SEE}	Description	Watt _{BASE}		
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	17.6	40% CFL 26W Pin Based & 60% PAR30/38	54.3	\$27	N/A
LED Interior Directional	LED Track Lighting	12.2	10% CMH PAR38 & 90% Halogen PAR38	60.4	\$59	N/A
	LED Wall-Wash Fixtures	8.3	40% CFL 42W Pin Base & 60% Halogen PAR38	17.7	\$59	N/A
LED Display Case	LED Display Case Light Fixture	7.1 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	\$11/ft	N/A
	LED Undercabinet Shelf-Mounted Task Light Fixtures	7.1 / ft	50% 2'T5 Linear & 50% 50W Halogen	36.2 / ft	\$11/ft	N/A
	LED Refrigerated Case Light, Horizontal or Vertical	7.6 / ft	5'T8	15.2 / ft	\$11/ft	N/A
	LED Freezer Case Light, Horizontal or Vertical	7.7 / ft	6'T12HO	18.7 / ft	\$11/ft	N/A
LED Linear Replacement Lamps	LED 4' Linear Replacement Lamp	18.7	50:50: Lamp only 32w T8:34w T12	29.1	\$24	93%
	LED 2' Linear Replacement Lamp	9.7	50:50: Lamp only 17w T8:20w T12	16.0	\$13	83%
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	34.1	50:50; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	59.5	\$48	90%
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	42.8	50:50; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	96.2	\$91	78%
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	37.9	50:50; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	59.5	\$62	88%
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	54.3	50:50; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	96.2	\$99	72%
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	72.7	50:50; 4-Lamp 32w T8 (BF < 0.88) :4-Lamp 34w T12 (BF < 0.88)	128.3	\$150	72%
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	18.1	50:50; 1-Lamp 32w T8 (BF <0.91) :1-Lamp 34w T12 (BF <0.88)	30.1	\$36	92%
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	39.6	50:50; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	59.5	\$76	87%
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	53.1	50:50; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	96.2	\$130	73%
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	19.7	50:50; 1-Lamp 32w T8 (BF <0.91) :1-Lamp 34w T12 (BF <0.88)	30.1	\$54	91%
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	37.8	50:50; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89)	59.5	\$104	88%
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	55.9	50:50; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88)	96.2	\$158	71%
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	62.6	T5HO 2L-F54T5HO - 4'	120.0	\$215	N/A
	LED Surface & Suspended	95.4	T5HO 3L-F54T5HO - 4'	180.0	\$374	N/A

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.4.5 LED Fixtures

LED Category	EE Measure		Baseline		Incremental Cost	Mid Life Savings Adjustment (2020)
	Description	Watt _{SEE}	Description	Watt _{BASE}		
	Linear Fixture, > 7500 lumens					
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, ≤ 10,000 lumens	90.3	3-Lamp T8HO Low-Bay	157.0	\$191	N/A
	LED High-Bay Fixtures, 10,001-15,000 lumens	127.5	4-Lamp T8HO High-Bay	196.0	\$331	N/A
	LED High-Bay Fixtures, 15,001-20,000 lumens	191.0	6-Lamp T8HO High-Bay	294.0	\$482	N/A
	LED High-Bay Fixtures, > 20,000 lumens	249.7	8-Lamp T8HO High-Bay	392.0	\$818	N/A
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	17.0	25% 73 Watt EISA Inc, 75% 1L T8	42.0	\$33	N/A
	LED Ag Interior Fixtures, 2,001-4,000 lumens	27.8	25% 146 Watt EISA Inc, 75% 2L T8	81.0	\$54	N/A
	LED Ag Interior Fixtures, 4,001-6,000 lumens	51.2	25% 217 Watt EISA Inc, 75% 3L T8	121.0	\$125	N/A
	LED Ag Interior Fixtures, 6,001-8,000 lumens	71.7	25% 292 Watt EISA Inc, 75% 4L T8	159.0	\$190	N/A
	LED Ag Interior Fixtures, 8,001-12,000 lumens	103.5	200W Pulse Start Metal Halide	227.3	\$298	N/A
	LED Ag Interior Fixtures, 12,001-16,000 lumens	143.8	320W Pulse Start Metal Halide	363.6	\$450	N/A
	LED Ag Interior Fixtures, 16,001-20,000 lumens	183.3	350W Pulse Start Metal Halide	397.7	\$595	N/A
	LED Ag Interior Fixtures, > 20,000 lumens	305.0	(2) 320W Pulse Start Metal Halide	727.3	\$998	N/A
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	42.6	100W Metal Halide	113.6	\$190	N/A
	LED Exterior Fixtures, 5,001-10,000 lumens	68.2	175W Pulse Start Metal Halide	198.9	\$287	N/A
	LED Exterior Fixtures, 10,001-15,000 lumens	122.5	250W Pulse Start Metal Halide	284.1	\$391	N/A
	LED Exterior Fixtures, > 15,000 lumens	215.0	400W Pulse Start Metal Halide	454.5	\$793	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	35,000	\$30.75	70,000	\$47.50	2,500	\$8.86	40,000	\$14.40
LED Interior Directional	LED Track Lighting	35,000	\$39.00	70,000	\$47.50	2,500	\$12.71	40,000	\$11.00
	LED Wall-Wash Fixtures	35,000	\$39.00	70,000	\$47.50	2,500	\$9.17	40,000	\$27.00
LED Display Case	LED Display Case Light Fixture	35,000	\$9.75/ft	70,000	\$11.88/ft	2,500	\$6.70	40,000	\$5.63

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
	LED Undercabinet Shelf-Mounted Task Light Fixtures	35,000	\$9.75/ft	70,000	\$11.88/ft	2,500	\$6.70	40,000	\$5.63
	LED Refrigerated Case Light, Horizontal or Vertical	35,000	\$8.63/ft	70,000	\$9.50/ft	15,000	\$1.13	40,000	\$8.00
	LED Freezer Case Light, Horizontal or Vertical	35,000	\$7.88/ft	70,000	\$7.92/ft	12,000	\$0.94	40,000	\$6.67
LED Linear Replacement Lamps	LED 4' Linear Replacement Lamp	35,000	\$8.57	70,000	\$13.67	24,000	\$6.17	40,000	\$11.96
	LED 2' Linear Replacement Lamp	35,000	\$5.76	70,000	\$13.67	24,000	\$6.17	40,000	\$11.96
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	35,000	\$46.68	70,000	\$40.00	24,000	\$26.33	40,000	\$35.00
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	35,000	\$56.31	70,000	\$40.00	24,000	\$39.50	40,000	\$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	35,000	\$49.58	70,000	\$40.00	24,000	\$12.33	40,000	\$35.00
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	35,000	\$57.76	70,000	\$40.00	24,000	\$18.50	40,000	\$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	35,000	\$68.89	70,000	\$40.00	24,000	\$24.67	40,000	\$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	35,000	\$43.43	70,000	\$40.00	24,000	\$6.17	40,000	\$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	35,000	\$52.31	70,000	\$40.00	24,000	\$12.33	40,000	\$35.00
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	35,000	\$63.86	70,000	\$40.00	24,000	\$18.50	40,000	\$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, ≤ 3000 lumens	35,000	\$45.01	70,000	\$40.00	24,000	\$6.17	40,000	\$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	35,000	\$58.73	70,000	\$40.00	24,000	\$12.33	40,000	\$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	35,000	\$73.50	70,000	\$40.00	24,000	\$18.50	40,000	\$35.00

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
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	35,000	\$88.69	70,000	\$40.00	30,000	\$26.33	40,000	\$60.00
	LED Surface & Suspended Linear Fixture, > 7500 lumens	35,000	\$123.91	70,000	\$40.00	30,000	\$39.50	40,000	\$60.00
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, ≤ 10,000 lumens	35,000	\$90.03	70,000	\$62.50	18,000	\$64.50	40,000	\$92.50
	LED High-Bay Fixtures, 10,001-15,000 lumens	35,000	\$122.59	70,000	\$62.50	18,000	\$86.00	40,000	\$92.50
	LED High-Bay Fixtures, 15,001-20,000 lumens	35,000	\$157.22	70,000	\$62.50	18,000	\$129.00	40,000	\$117.50
	LED High-Bay Fixtures, > 20,000 lumens	35,000	\$228.52	70,000	\$62.50	18,000	\$172.00	40,000	\$142.50
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, ≤ 2,000 lumens	35,000	\$37.00	70,000	\$40.00	1,000	\$1.23	40,000	\$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	35,000	\$44.96	70,000	\$40.00	1,000	\$1.43	40,000	\$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	35,000	\$63.02	70,000	\$40.00	1,000	\$1.62	40,000	\$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	35,000	\$79.78	70,000	\$40.00	1,000	\$1.81	40,000	\$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	35,000	\$119.91	70,000	\$62.50	15,000	\$63.00	40,000	\$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	35,000	\$151.89	70,000	\$62.50	15,000	\$68.00	40,000	\$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	35,000	\$184.62	70,000	\$62.50	15,000	\$73.00	40,000	\$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	35,000	\$285.75	70,000	\$62.50	15,000	\$136.00	40,000	\$202.50
LED Exterior Fixtures	LED Exterior Fixtures, ≤ 5,000 lumens	35,000	\$86.92	70,000	\$62.50	15,000	\$58.00	40,000	\$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	35,000	\$111.81	70,000	\$62.50	15,000	\$63.00	40,000	\$112.50
	LED Exterior Fixtures, 10,001-15,000 lumens	35,000	\$138.32	70,000	\$62.50	15,000	\$68.00	40,000	\$122.50
	LED Exterior Fixtures, > 15,000 lumens	35,000	\$223.67	70,000	\$62.50	15,000	\$73.00	40,000	\$132.50

MEASURE CODE: NR-LTG-LDFX-V01-170101

SUNSET DATE: 1/1/2018

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 luminaries per project, especially for large commercial projects, thus increasing energy savings further.⁴¹⁸

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 years⁴¹⁹.

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:

⁴¹⁸ Lighting Research Center. T5 Fluorescent Systems. <http://www.lrc.rpi.edu/programs/nlpiip/lightingAnswers/lat5/abstract.asp>

⁴¹⁹ Focus on Energy Evaluation “Business Programs: Measure Life Study” Final Report, August 9, 2009 prepared by PA Consulting Group.

Watt _{Base}	= Input wattage of the baseline system is dependant on new fixture configuration and found in the 'T5HO Efficient and Baseline Wattage and Cost Assumptions' reference table below.
Watt _{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% ⁴²⁰ .

Heating Penalty:

If electrically heated building⁴²¹:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFkWh)$$

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):

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * Hours * (-IFTtherms)$$

⁴²⁰ Based upon review of PY5-6 evaluations from ComEd, IL commercial lighting program (BILD)

⁴²¹ Negative value because this is an increase in heating consumption due to the efficient lighting.

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 3.4⁴²². 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

= 197⁴²³

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.

⁴²² Negative value because this is an increase in heating consumption due to the efficient lighting.

⁴²³ Number of days where HDD 55 >0.

REFERENCE TABLES

T5HO Efficient and Baseline Wattage And Cost Assumptions⁴²⁴

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 Lifetimes⁴²⁵

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-VO1-170101

SUNSET DATE: 1/1/2019

⁴²⁴ 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.

⁴²⁵ Costs include labor cost – see “Updated-T5HO-adjusted deemed costs.baselines-7-30-15.xlsx” for more information.

3.4.7 High Performance and Reduced Wattage T8 Fixtures and Lamps

DESCRIPTION

This measure applies to “High Performance T8” (HPT8) lamp/ballast systems that have higher lumens per watt than standard T8 or T12 systems and produce equal or greater light levels than standard T8 lamps while using fewer watts, as well as “Reduced Wattage T8 lamps” or RWT8 lamps. The characterization applies to the installation of new equipment on existing lighting T8 systems with efficiencies that exceed that of the equipment that would have been installed following standard market practices, as well as opportunities to relamp/reballast.

If the implementation strategy does not allow for the installation location to be known, the utility will deem a split between Commercial and Residential use.

Whenever possible, site-specific costs and hours of use should be used for savings calculations. Default new and baseline assumptions have been provided in the reference tables alongside default component costs and lifetimes for Operating and Maintenance Calculations.

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 efficient conditions for TOS and RF applications are a qualifying HP or RWT8 fixture with a ballast factor < 0.79 and lamp/ballast combinations listed on the CEE website under qualifying HP T8 products⁴²⁶ and qualifying RWT8 products⁴²⁷.

DEFINITION OF BASELINE EQUIPMENT

For Time of Sale: The baseline condition will vary depending on the characterization of the fixture installed (e.g., the number of lamps). For default purposes, the baseline is assumed to be a 50:50 split of T8 system/T12 systems⁴²⁸. This assumption should be reviewed annually to ensure it still reflects an appropriate baseline assumption.

For Retrofit: The baseline condition is assumed to be the existing lighting fixture.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of efficient equipment is capped at 15 years⁴²⁹.

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

⁴²⁶ <http://library.cee1.org/content/cee-high-performance-t8-specification>

⁴²⁷ <http://library.cee1.org/content/reduced-wattage-t8-specification>

⁴²⁸ Based on lighting expert knowledge of the market prevalence of T12s given the 2010 Federal mandate banning T12 production.

⁴²⁹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * WHF_e * ISR$$

Where:

- Watts_{Base} = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp). Value can be selected from the reference table at the end of the characterization.
- Watts_{EE} = New Input wattage of EE fixture, which depends on new fixture configuration. Value can be selected from the appropriate reference table at the end of the characterization, or a custom value can be used.
- 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.
- WHF_e = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section x for each building type. If building is un-cooled, the value is 1.0.
- ISR = In Service Rate is assumed to be 100%

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; 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.

Mid Life Adjustment:

A midlife savings adjustment should be applied in 2020 to account for the baseline lamp replacement assumption changing from a blended 50/50 Standard T8/T12 to 100% Standard T8 by 2020⁴³⁰. The savings adjustment is calculated as follows, and is provided in the HP/RW T8 Reference Table below:

$$\% Adjustment = \left(\frac{Watts_{T8base} - Watts_{EE}}{Watts_{Blended\ T8/T12\ Base} - Watts_{EE}} \right)$$

Where:

- Watts_{T8Base} = Input wattage of the existing system based on 100% T8 fixture; see reference table below.
- Watts_{BlendedT8/T12} = Input wattage of the existing system based on 50% T8 / 50% T12; see reference

⁴³⁰ As of July 1, 2010, a Federal mandate states that the magnetic ballasts used in many T12 fixtures can no longer be produced for commercial and industrial applications. However, there have been many loopholes that have meant T12 lamps continue to hold a significant market share. It is expected that new mandates will close the loophole within the next few years. T12 lamps have an average life of 20,000 hours and if we assume they are operated on average for 4500 hours annually, this would mean a lamp would have to be replaced every 4.5 years. We therefore assume that by 2020 all replacement lamps are Standard T8s. Therefore, while the more likely scenario would be a gradual shift of the 50/50 weighted baseline to T8s over the timeframe, to simplify this assumption, a single midlife adjustment in 2020 is assumed.

table below.

SUMMER COINCIDENT DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * ISR * WHFd * CF$$

Where:

WHF_d = 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, WHF_d 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 impacts⁴³¹; 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 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

= 197⁴³²

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Actual operation and maintenance costs will vary by specific equipment installed/replaced. See reference table below.

⁴³¹ Negative value because this is an increase in heating consumption due to the efficient lighting.

⁴³² Number of days where HDD 55 >0.

REFERENCE TABLES⁴³³

EE Measure Description	Watts _{EE}	Baseline Description	T12/T8Watts _{BASE}	T8 Watts _{BASE}	Incremental Cost	Mid Life Savings Adjustment (2020)
1-Lamp 32w HPT8 (BF < 0.79)	24	50:50 T12:Standard T8	30.1	29	\$15.00	84%
2-Lamp 32w HPT8 (BF < 0.77)	48	50:50 T12:Standard T8	59.5	57	\$17.50	78%
3-Lamp 32w HPT8 (BF < 0.76)	71	50:50 T12:Standard T8	96.2	84	\$20.00	53%
4-Lamp 32w HPT8 (BF < 0.78)	98	50:50 T12:Standard T8	128.3	113	\$22.50	48%
6-Lamp 32w HPT8 (BF < 0.76)	142	50:50 T12:Standard T8	192.5	169	\$40.00	53%
1-Lamp 28w RWT8 (BF < 0.76)	21	50:50 T12:Standard T8	30.1	29	\$15.00	89%
2-Lamp 28w RWT8 (BF < 0.76)	43	50:50 T12:Standard T8	59.5	57	\$17.50	85%
3-Lamp 28w RWT8 (BF < 0.77)	63	50:50 T12:Standard T8	96.2	84	\$20.00	65%
4-Lamp 28w RWT8 (BF < 0.79)	88	50:50 T12:Standard T8	128.3	113	\$22.50	61%
6-Lamp 28w RWT8 (BF < 0.77)	126	50:50 T12:Standard T8	192.5	169	\$40.00	65%

EE Measure Description	Lamp Qty	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost	T12/T8 Lamp Life (hrs) ⁴³⁴	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
1-Lamp 32w HPT8 (BF < 0.79)	1	24,000	\$8.17	70,000	\$52.50	22000	\$5.67	55,000	\$35.00
2-Lamp 32w HPT8 (BF < 0.77)	2	24,000	\$16.34	70,000	\$52.50	22000	\$11.33	55,000	\$35.00
3-Lamp 32w HPT8 (BF < 0.76)	3	24,000	\$24.51	70,000	\$52.50	22000	\$17.00	55,000	\$35.00
4-Lamp 32w HPT8 (BF < 0.78)	4	24,000	\$32.68	70,000	\$52.50	22000	\$22.67	55,000	\$35.00
6-Lamp 32w HPT8 (BF < 0.76)	6	24,000	\$49.02	70,000	\$105.00	22000	\$34.00	55,000	\$35.00
1-Lamp 28w RWT8 (BF < 0.76)	1	18,000	\$8.17	70,000	\$52.50	22000	\$5.67	55,000	\$35.00
2-Lamp 28w RWT8 (BF < 0.76)	2	18,000	\$16.34	70,000	\$52.50	22000	\$11.33	55,000	\$35.00
3-Lamp 28w RWT8 (BF < 0.77)	3	18,000	\$24.51	70,000	\$52.50	22000	\$17.00	55,000	\$35.00
4-Lamp 28w RWT8 (BF < 0.79)	4	18,000	\$32.68	70,000	\$52.50	22000	\$22.67	55,000	\$35.00

⁴³³ Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. See "Updated-HPT8 TRM Reference Tables7-30-15.xlsx" for more information and specific product links. Currently, 25WT8 are not considered under this measure as their lower light trade off and limitations on temperature and dimming have caused most distributors/contractors to use 28W almost exclusively in other markets.

⁴³⁴ 50:50 T8/T12 baseline lamp life based on assumed lamp life of 20,000 hrs for T12 and 24,000 hrs for T8.

EE Measure Description	Lamp Qty	EE Measure				Baseline			
		Lamp Life (hrs)	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost	T12/T8 Lamp Life (hrs) ⁴³⁴	Total Lamp Replacement Cost	Ballast Life (hrs)	Total Ballast Replacement Cost
6-Lamp 28w RWT8 (BF < 0.77)	6	18,000	\$49.02	70,000	\$105.00	22000	\$34.00	55,000	\$35.00

MEASURE CODE: NR-LTG-HPT8-V01-170101

SUNSET DATE: 1/1/2019

3.4.8 Metal Halide

DESCRIPTION

This measure addresses the installation of high efficiency pulse start metal halide fixtures and lamps in place of a standard metal halide. Pulse start metal halide luminaires produce more lumens per watt and have an improved lumen maintenance compared to standard probe start technology. Similarly the high efficiency pulse start metal halide ballast lasts longer than a standard system due to their cooler operating temperatures.⁴³⁵

This measure was developed to be applicable for Retrofit (RF) program.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is an EISA-compliant pulse start metal halide lamp and ballasts for luminaires. Under 2009 federal rulings metal halide ballasts in low-watt options (150W-500W fixtures) must be pulse start and have a minimum ballast efficiency of 88%.⁴³⁶ Amendments made in 2014 will require more stringent energy conservation standards with compliance required by February 10, 2017⁴³⁷.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing bulb and fixture. If unknown assume, High Intensity Discharge (HID) Metal Halide lighting with probe start fixture and a standard ≤ 400 Watt lamp.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years⁴³⁸.

DEEMED MEASURE COST

Where actual costs are unknown, the incremental capital cost is assumed to be \$267⁴³⁹

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

⁴³⁵ Building a Brighter Future: Your Guide to EISA-Compliant Ballast and Lamp Solutions from Philips Lighting: <http://1000bulbs.com/pdf/advance%20eisa%20brochure.pdf>

⁴³⁶ Under EISA rulings metal halide ballasts in low-watt options must be pulse start and have a minimum ballast efficiency of 88%. This ruling virtually eliminates the manufacture of probe start (ceramic) fixtures but some exemptions exist including significantly the 150w wet location fixtures (as rated per NEC 2002, section 410.4 (A)). These will be replaced by 150W. Department of Energy – 10 CFR Part 431 – Energy Conservation Program: Energy Conservation Standards for Metal Halide Lamp Fixtures; Final Rule 7746 Federal Register / Vol. 79, No. 27 / Monday, February 10, 2014 / Rules and Regulations <https://www.federalregister.gov/articles/2014/02/10/2014-02356/energy-conservation-program-energy-conservation-standards-for-metal-halide-lamp-fixtures#h-9>

⁴³⁷ The revised 2014 efficiency standards for metal halides require that luminaires produced on or after February 10th, 2017 must **not** contain a probe-start metal halide ballast. Exceptions to this ruling include, metal halide luminaires with a regulated-lag ballast, that utilize an electronic ballasts which operates at 480V and those which utilize a high-frequency (≥ 1000 Hz) electronic ballast. Department of Energy – 10 CFR Part 431 – Energy Conservation Program: Energy Conservation Standards for Metal Halide Lamp Fixtures; Final Rule 7746 Federal Register / Vol. 79, No. 27 / Monday, February 10, 2014 / Rules and Regulations <https://www.federalregister.gov/articles/2014/02/10/2014-02356/energy-conservation-program-energy-conservation-standards-for-metal-halide-lamp-fixtures#h-9>

⁴³⁸ GDS Associates, *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*, June 2007, http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

⁴³⁹ Assuming cost of lamp and fixture combined per Itron, Inc. *2010-2012 W0017 Ex Ante Measure Cost Study – Final Report (Deemed Measures)*, May 27, 2014.

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 existing system which depends on the baseline fixture configuration (number and type of lamp). Value can be selected from the reference table at the end of the characterization or a custom value can be used.
- Watts_{EE} = New Input wattage of EE fixture, which depends on new fixture configuration. Value can be selected from the appropriate reference table at the end of the characterization, or a custom value can be used.
- 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.
- 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 percentage of units rebated that get installed is assumed to be 97%⁴⁴⁰

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; 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:

- WHF_d = 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.

⁴⁴⁰ Itron, Verification of Reported Energy and Peak Savings from the EmPOWER Maryland Energy Efficiency Programs, April 21, 2011; IA specific value should be determined with subsequent evaluations.

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 impacts⁴⁴¹; 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 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
 = 197⁴⁴²

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Actual operation and maintenance costs will vary by specific equipment installed/replaced. See reference table below.

REFERENCE TABLES⁴⁴³

Lamp Watt _{EE}	Efficient Fixture Ballast	Efficient System Lumen	System Watt _{EE}	Lamp Watt _{Base}	Baselines Ballast ⁴⁴⁴	System Watts _{Base}	Baseline System Lumen
Pulse Start MH 150W	Pulse Start-CWA Ballast	10500	185	Probe Start MH 175W	standard C&C	210	9100
Pulse Start MH 175W	Pulse Start-CWA Ballast	11200	208	Probe Start MH 175W	standard C&C	210	9100
Pulse Start MH 200W	Pulse Start-CWA Ballast	16800	232	Probe Start MH250W	standard C&C	295	13500
Pulse Start MH 250W	Pulse Start-CWA Ballast	16625	290	Probe Start MH250W	standard C&C	295	13500

⁴⁴¹ Negative value because this is an increase in heating consumption due to the efficient lighting.

⁴⁴² Number of days where HDD 55 >0.

⁴⁴³ Per lamp/ballast

⁴⁴⁴ Standard Magnetic Core and Coil ballast systems are common for Metal Halide lamp wattages 175-400. See Panasonic “Metal Halide: Probe Start vs. Pulse Start”

Lamp Watt _{EE}	Efficient Fixture Ballast	Efficient System Lumen	System Watt _{EE}	Lamp Watt _{Base}	Baselines Ballast ⁴⁴⁴	System Watts _{Base}	Baseline System Lumen
Pulse Start MH 320W	Pulse Start-CWA Ballast	21000	368	Probe Start MH400W	standard C&C	458	24000
Pulse Start MH350W	Pulse Start-CWA Ballast	25200	400	Probe Start MH400W	standard C&C	458	24000
Pulse Start MH 400W	Pulse Start-CWA Ballast	29820	452	Probe Start MH400W	standard C&C	458	24000

MEASURE CODE: NR-LTG-PSMH-V01-170101

SUNSET DATE: 1/1/2019

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) or incandescent 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 watts⁴⁴⁵. 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: Time of Sale (TOS), 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.⁴⁴⁶

DEFINITION OF BASELINE EQUIPMENT

For TOS the baseline equipment is assumed to be a compact fluorescent unit (CFL)⁴⁴⁷. For RF/DI the baseline is the existing system (either a CFL or incandescent unit)

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 13 years⁴⁴⁸.

DEEMED MEASURE COST

The incremental cost for this measure is assumed as follows⁴⁴⁹.

For TOS when considering the capital incremental cost of a CFL unit to LED unit assume \$0.⁴⁵⁰

For DI and RF it is assumed at \$49⁴⁵¹

LOADSHAPE

Loadshape E01 – Flat

⁴⁴⁵ ENERGY STAR “Save Energy, Money and Prevent Pollution with LED Exit Signs”

⁴⁴⁶ 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.

⁴⁴⁷ Incandescent exit sign units are no longer available for purchase in the market per the ENERGY STAR Exit Sign Calculator assumptions.

⁴⁴⁸ GDA Associates Inc. “Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures”, June 2007.

⁴⁴⁹ EPA ENERGY STAR Exit Sign Calculator estimates LED cost/unit is \$39 and assuming IA labor cost of 15 minutes @ \$40/hr.

⁴⁵⁰ CFL exit sign units on average cost more than LED exit sign units. Inform Inc. “Purchasing for Pollution Prevention Program Fact Sheet”, Nov 2003.

⁴⁵¹ Price includes new exit sign/fixture and installation. EPA ENERGY STAR Exit Sign Calculator estimates LED cost/unit is \$39 and assuming IA labor cost of 15 minutes @ \$40/hr.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS ⁴⁵²

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * WHF_e$$

Where:

Watts_{Base} = Actual wattage if known, if unknown assume the following:

Program Type	Baseline Type	Watts _{Base}
Retrofit/Direct Install ⁴⁵³	Incandescent (dual sided)	40W ⁴⁵⁴
	Incandescent (single sided)	20W
	CFL (dual sided)	14W ⁴⁵⁵
	CFL (single sided)	7W
Time of Sale	CFL (dual sided)	14W
	CFL (single sided)	7W

Watts_{EE} = Actual wattage if known, if unknown assume singled sided 2W and dual sided 4W⁴⁵⁶

Hours = Annual operating hours
= 8766

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.

HEATING PENALTY

If electrically heated building⁴⁵⁷:

$$\Delta kWh_{heatpenalty} = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * (-IFkWh)$$

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

⁴⁵² 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).

⁴⁵³ If program type does not know baseline assume the ratio of present incandescent to fluorescent exit sign units to be a deemed baseline of 70% incandescent to 30% CFL = 32.2W. This ratio has been used by ComEd, IL and is reflective of program experience. In lieu of IA specific market research, we consider this evaluation to be reasonable.

⁴⁵⁴ Average incandescent watts are assumed at 40W 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.

⁴⁵⁵ 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>

⁴⁵⁶ 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>

⁴⁵⁶ 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>

⁴⁵⁷ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

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

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * WHF_d * CF$$

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. If unknown, use the Nonresidential average value.

CF = Summer Peak Coincidence Factor for this measure
= 1.0⁴⁵⁸

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated buiding (or if heating is unknown)⁴⁵⁹:

$$\Delta Therms = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours * (-IFTherms)$$

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.

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
= 197⁴⁶⁰

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

⁴⁵⁸ Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

⁴⁵⁹ Results in a negative value because this is an increase in heating consumption due to the efficient lighting.

⁴⁶⁰ Number of days where HDD 55 >0.

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 ⁴⁶¹	CFL lamp	\$13.00 ⁴⁶²	0.57 years ⁴⁶³
	Incandescent lamp	\$11.27 ⁴⁶⁴	0.17 years ⁴⁶⁵
Time of Sale	CFL lamp	\$13.00	0.57 years

MEASURE CODE: NR-LTG-EXIT-V01-170101

SUNSET DATE: 1/1/2019

⁴⁶¹ If program component is unknown use 70/30 split for costs and life = \$11.87 and 0.29 yrs

⁴⁶² 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).

⁴⁶³ 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.

⁴⁶⁴ Assume incandescent A-lamp 45W is \$1.27 per Itron, Ex Ante Measure cost Study, 2014 “WA017_MCS Results Matrix - Volume I (1).xlsx”

⁴⁶⁵ ENERGY STAR “Save Energy, Money and Prevent Pollution with LED Exit Signs” specifies that a typical incandescent exit sign bulb will be approx. 40W and will have a rated life of 500-2000 hours. Given 24/7 run time of the Exit Sign the replacement requirements would be an average of 1500/8766.

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.⁴⁶⁶

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 only⁴⁶⁷.

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 characteristics⁴⁶⁸ 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 years⁴⁶⁹.

DEEMED MEASURE COST ⁴⁷⁰

Actual measure installation cost should be used (including material and labor⁴⁷¹) Use actual costs of LED unit when know. If unknown use the default values/luminaire provided below:

⁴⁶⁶ 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>

⁴⁶⁷ 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.

⁴⁶⁸ 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>

⁴⁶⁹ 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>

⁴⁷⁰ 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).

⁴⁷¹ 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 SAVINGS⁴⁷²

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hours$$

Where:

$Watts_{Base}$ = Actual wattage if known, if unknown assume the following nominal wattage based on technology.

Metal Halide = 250W⁴⁷³

Mercury Vapor = 175W⁴⁷⁴

High Pressure Sodium = 170W⁴⁷⁵:

$Watts_{EE}$ = Actual wattage⁴⁷⁶.

Baseline Measure			Efficiency Measure		
Baseline Technology	Typical Net Efficacy (lm/Watt) ⁴⁷⁷	Nominal WattsBASE ⁴⁷⁸	Efficient Technology	Typical Net Efficacy (lm/Watt)	Nominal WattsEE ⁴⁷⁹
HPS	32-68	170	LED	36-90	Actual
MV	10-17	175	LED	36-90	Actual
MH	21-34	250	LED	36-90	Actual

⁴⁷² There is no ISR calculation. Savings are per unit.

⁴⁷³ 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)

⁴⁷⁴ Based on averaging Mercury Vapor information provided in IA custom LED street lighting installations and NEEP Street Lighting Assessment (175W)

⁴⁷⁵ 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)).

⁴⁷⁶ It is important to ensure that retrofit opportunities base efficient wattage on a lumen per watt equivalence.

⁴⁷⁷ Typical lumen/watt range taken from Clinton Climate Initiative report "Street Lighting Retrofit Projects: Improving performance while reducing costs and greenhouse gas emissions" June, 2010

⁴⁷⁸ Nominal WattsBASE based on averaging the nominal wattages of baseline street-lighting technologies reported in IA custom data and through NEEP's "LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic", January 2015

⁴⁷⁹ When submitting the list of fixtures for replacement, some fixtures may require specific lighting level adjustments. As such the actual WattsEE should always be provided after identifying any potential changes with a lighting professional and assessment of lighting needs.

Hours = Annual operating hours - use approximate annual run time of 4100 hours⁴⁸⁰.

SUMMER COINCIDENT PEAK DEMAND SAVINGS⁴⁸¹

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * CF$$

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

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M costs are estimated at \$50/LED luminaire annually.⁴⁸²

MEASURE CODE: NR-LTG-STLT-V01-170101

SUNSET DATE: 1/1/2019

⁴⁸⁰ 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

⁴⁸¹ On-peak savings for street lighting occur mostly in the winter. Only off-peak demand savings occur during the summer months.

⁴⁸² 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

DESCRIPTION

Light emitting diodes (LED) traffic and pedestrian signals are an efficient and effective alternative to traditional incandescent signals due to their low power consumption, performance in cooler temperatures and very long life. LED traffic signal lamps typically use 80 to 90 percent less energy than the incandescent lamps that they replace and the longer life expectancies of LED traffic signal lamps can reduce maintenance costs over incandescent technology by approximately 75 percent, making the payback of a retrofit project as short as one to three years⁴⁸³.

This measure was developed to be applicable to the Retrofit (RF) program

DEFINITION OF EFFICIENT EQUIPMENT

The Energy Policy Act of 2005 requires all LED traffic signal fixtures to meet the minimum performance requirements as listed by the ENERGY STAR Traffic Signal Specification that include arrow and pedestrian signal modules⁴⁸⁴.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing incandescent traffic signal lighting technology. See reference tables below for baseline efficiencies and assumptions.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of an LED traffic signal is 100,000 hours (manufacturer’s estimate), capped at 10 years.⁴⁸⁵ The life in years is calculated by dividing 100,000 hrs by the annual operating hours for the particular signal type.

DEEMED MEASURE COST

Actual measure installation cost should be used (including material and labor).

LOADSHAPE

- Loadshape NREL18 - Traffic Signal - Red Balls, always changing or flashing
- Loadshape NREL19 - Traffic Signal - Red Balls, changing day, off night
- Loadshape NREL20 - Traffic Signal - Green Balls, always changing
- Loadshape NREL21 - Traffic Signal - Green Balls, changing day, off night
- Loadshape NREL22 - Traffic Signal - Red Arrows
- Loadshape NREL23 - Traffic Signal - Green Arrows
- Loadshape NREL24 - Traffic Signal - Flashing Yellows
- Loadshape NREL25 - Traffic Signal - “Hand” Don’t Walk Signal
- Loadshape NREL26 - Traffic Signal - “Man” Walk Signal
- Loadshape NREL27 - Traffic Signal - Bi-Modal Walk/Don’t Walk

⁴⁸³ See LED Traffic Light FAQs http://www.appropedia.org/LED_traffic_light_FAQ

⁴⁸⁴ ENERGY STAR Program Requirements for Traffic Signals: Eligibility Criteria. See: https://www.energystar.gov/ia/partners/product_specs/eligibility/traffic_elig.pdf and <http://www.ite.org/standards/led/signals.asp>

⁴⁸⁵ Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Measure Life Study, KEMA, August 25, 2009

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Watts_{Base} - Watts_{EE}}{1,000} * Hour$$

Where:

- $Watts_{Base}$ =The connected load of the baseline equipment
= see reference tables below “Table ‘Traffic Signals Technology Equivalencies’
- $Watts_{EE}$ =The connected load of the baseline equipment
= see reference tables below “Table ‘Traffic Signals Technology Equivalencies’
- $Hours$ = annual operating hours of the lamp
= see reference tables below “Table ‘Traffic Signals Technology Equivalencies’

COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{Watts_{Base} - Watts_{EE}}{1,000} * CF$$

Where:

- CF = Peak coincidence factor for measure

The peak coincidence factor (CF) for this measure is dependent on lamp type as outlined below:

Lamp Type	CF ⁴⁸⁶
Red Round, always changing or flashing	0.55
Red Arrows	0.90
Green Arrows	0.10
Yellow Arrows	0.03
Green Round, always changing or flashing	0.43
Flashing Yellow	0.50
Yellow Round, always changing	0.02
“Hand” Don’t Walk Signal	0.75
“Man” Walk Signal	0.21

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

⁴⁸⁶ ACEEE, (1998) A Market Transformation Opportunity Assessment for LED Traffic Signals, <http://www.cee1.org/gov/led/led-ace3/ace3led.pdf>

REFERENCE TABLES⁴⁸⁷

Traffic Signals Technology Equivalencies⁴⁸⁸

Flashing Signal	Fixture Size and Color	Efficient Lamps	Baseline Lamps	HOURS	Watts EE	Watts Base	Energy Savings (in kWh)
Round Signals	8" Red	LED	Incandescent	4820	7	69	299
Round Signals	12" Red	LED	Incandescent	4820	6	150	694
Round Signals	8" Yellow	LED	Incandescent	175	10	69	10
Round Signals	12" Yellow	LED	Incandescent	175	13	150	24
Round Signals	8" Green	LED	Incandescent	3675	9	69	221
Round Signals	12" Green	LED	Incandescent	3675	12	150	507
Flashing Signal	8" Red	LED	Incandescent	4380	7	69	272
Flashing Signal	12" Red	LED	Incandescent	4380	6	150	631
Flashing Signal	8" Yellow	LED	Incandescent	4380	10	69	258
Flashing Signal	12" Yellow	LED	Incandescent	4380	13	150	600
Turn Arrows	8" Yellow	LED	Incandescent	701	7	116	76
Turn Arrows	12" Yellow	LED	Incandescent	701	9	116	75
Turn Arrows	8" Green	LED	Incandescent	940	7	116	102
Turn Arrows	12" Green	LED	Incandescent	940	7	116	102
Pedestrian Sign	12" Hand/Man	LED	Incandescent	8760	8	116	946

MEASURE CODE: NR-LTG-LDTP-VO1-170101

SUNSET DATE: 1/1/2019

⁴⁸⁷ Reference table uses specific models and manufacturers specification to determine WattsEE and WattsBase. These are recorded as having the predominant market share per Missouri Department of Transportation “Life Expectancy Evaluation and Development of a Replacement Schedule for LED Traffic Signals”, March 2011.

⁴⁸⁸ See “LED Traffic and Pedestrian Signal-Tables.xlsx”. Note it is advised that the incremental cost data be updated with IA specific data where available in this table.

3.4.12 Occupancy Sensor

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 pattern⁴⁸⁹.

This measure relates to the installation of interior occupancy sensors on an existing lighting system (not replacement). Lighting control types covered by this measure include switch-mounted, remote-mounted, and fixture-mounted. It does not cover automatic photo sensors, time clocks, and energy management systems. All sensors must be hard wired and control interior 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

It is assumed that this measure characterization applies to only those automatic controlled lighting occupancy sensors that control a minimum average wattage greater than 45W per control.

DEFINITION OF BASELINE EQUIPMENT

The baseline efficiency case assumes lighting fixtures with no occupancy controls. 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for all lighting controls is assumed to be 8 years⁴⁹⁰.

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 ⁴⁹¹
Full cost of switch (wall) mounted occupancy sensor (interior)	\$54
Full cost of fixture (bi-level) mounted occupancy sensor	\$67
Full cost of remote (ceiling) mounted occupancy sensor	\$105

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

⁴⁸⁹ United States Department of the Interior. Greening the Department of Interior. <http://www.doi.gov/archive/greening/energy/occupy.html>

⁴⁹⁰ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

⁴⁹¹ Based on averaging typical prices quoted by online vendors. See reference table “Occupancy Sensor Reference Costs 2015.xls” for more information.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kW_{Controlled} * Hours * ESF * WHF_e$$

Where:

$kW_{Controlled}$ = Total lighting load connected to the control in kilowatts. Savings is per control. The total connected load per control should be collected from the customer, or use the default values presented below used;

Lighting Control Type Interior	Default kW controlled ⁴⁹²
Switch (wall) mounted occupancy sensor	0.304 (per control)
Fixture-mounted occupancy sensor	0.180 (per fixture)
Remote (ceiling) mounted occupancy sensor	0.517 (per control)

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 by Lighting Reference Table in Section 3.4. If building type is unknown, use the Nonresidential Average value.

ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system). Determined on a site-specific basis or using the default values below:

Lighting Control Type	Energy Savings Factor ⁴⁹³
Switch (wall) mounted occupancy sensor	24%
Fixture-mounted sensor	24%
Remote (ceiling) mounted occupancy sensor	24%

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 building⁴⁹⁴:

$$\Delta kWh_{heatpenalty} = kW_{Controlled} * Hours * ESF * (-IFkWh)$$

Where:

IFkWh = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the

⁴⁹² Based on review of custom Efficiency Vermont program data of installed occupancy sensors from 2009-2014. See reference table "Updated-Occupancy-Sensor-ReferenceCosts-7-30-15.xls".

⁴⁹³ 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 installations. 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 are set, etc. As such, their value of 24% represented the best conservative estimate of occupancy controls energy savings achievable in the field today.

⁴⁹⁴Negative 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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kW_{Controlled} * WHFd * (CF_{baseline} - CF_{os})$$

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
- CFbaseline = 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.
- CFos = Retrofit Summer Peak Coincidence Factor the lighting system with Occupancy Sensors installed is 0.15 regardless of building type.⁴⁹⁵

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 is provided in the Lighting Reference Table in Section 3.4 by building type.

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
- 365 = Days per year

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-OSLC-V01-170101

⁴⁹⁵ RLW Analytics, Coincidence Factor Study Residential and Commercial Industrial Lighting Measures. Spring 2007.

SUNSET DATE: 1/1/2019

3.4.13 Daylighting Control

Daylight sensor lighting controls are devices that reduce lumen output levels in response to the amount of daylight available in a given area. Such systems save energy by either shutting off lights completely or dimming when there is adequate natural light available.

This measure relates to the installation of interior daylight controls on an existing lighting system (not replacement). Daylight sensors lighting controls covered by this measure include “on or off”, stepped dimming systems, such as dual ballast (high/low HID⁴⁹⁶ 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 and RF.

DEFINITION OF EFFICIENT EQUIPMENT

It is assumed that this measure characterization applies to only those daylighting sensor lighting controls that regulate a minimum average wattage greater than 45W per control and are accompanied by a daylight harvesting ballast system that meet current CEE specifications at full light output⁴⁹⁷. This measure includes both hard-wired and wireless controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is no daylight control sensor and lighting operated at normal power levels, controlled with a manual switch.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for all lighting controls is assumed to be 8 years⁴⁹⁸.

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

Photosensor control type	Cost per control ⁴⁹⁹
Fixture-Mounted daylight Sensor (per ballast controlled)	\$50
Remote-Mounted daylight Sensor (per ballast controlled)	\$65

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

⁴⁹⁶ Per the Uniformed Methods Project: *Methods for Determining Energy Efficiency Savings for Specific Measures: Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol*, 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.

⁴⁹⁷ Visit <http://library.cee1.org/content/commercial-lighting-qualifying-products-lists>

⁴⁹⁸ See “DEER2014-EUL-table-update_2014-02-05.xlsx” or <http://www.deeresources.com/>

⁴⁹⁹ Based on averaging typical prices quoted by online vendors and Efficiency Vermont based control data. See reference table “daylight-Sensor-ReferenceCosts-2015.xls”

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS⁵⁰⁰

$$\Delta kWh = kW_{Controlled} * Hours * ESF * WHFe$$

Where:

$kW_{Controlled}$ = Total lighting load connected to the control in kilowatts. Savings is an average per control or ballast as outlined below. The total connected load per control should be collected from the customer, or use the default values presented below used;

Lighting control type	Default kW controlled ⁵⁰¹
Fixture-mounted daylight sensor (per ballast)	73
Remote-mounted daylight sensor (per control)	350

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 by Lighting Reference Table in Section 3.4. If building type is unknown, use the Nonresidential Average value.

ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system). Determined on a site-specific basis or using the default energy saving factor of 28%⁵⁰².

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 building⁵⁰³:

$$\Delta kWh_{heatpenalty} = kW_{Controlled} * Hours * ESF * (-IFkWh)$$

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 3.4.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kW_{Controlled} * WHFd * CF$$

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

⁵⁰⁰ It is assumed an ISR of 100%

⁵⁰¹ Based on averaging typical prices quoted by online vendors and Efficiency Vermont based control data. See reference table "daylight-Sensor-ReferenceCosts-2015.xls"

⁵⁰² Lawrence Berkeley National Laboratory. A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. Page & Associates Inc. 2011.

⁵⁰³ Negative value because this is an increase in heating consumption due to the efficient lighting.

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

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 is provided in the Lighting Reference Table in Section 3.4 by building type.

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
 = 197⁵⁰⁴

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-DAYC-170101

SUNSET DATE: 1/1/2019

⁵⁰⁴ Number of days where HDD 55 >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)⁵⁰⁵. 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 years⁵⁰⁶.

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 \$274⁵⁰⁷.

LOADSHAPE

Loadshape NREL01:16 – Nonresidential Lighting (by Building Type)

Algorithm

CALCULATION OF SAVINGS

⁵⁰⁵ ASHRAE 90.1-2010, IECC 2012 Lutron “Code Compliance, Commercial Application Guide”.

⁵⁰⁶ GDS Associates, Measure Life Report “Residential and Commercial/Industrial Lighting and HVAC Measures June, 2007

⁵⁰⁷ 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.

ELECTRIC ENERGY SAVINGS⁵⁰⁸

$$\Delta kWh = KW_{Controlled} * Hours * ESF * WHF_e$$

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%⁵⁰⁹
- 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 building⁵¹⁰:

$$\Delta kWh_{heatpenalty} = KW_{Controlled} * Hours * ESF * (-IFkWh)$$

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.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = KW_{controlled} * ESF * WHF_d * CF$$

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 3.4.
- CF = Summer Peak Coincidence Factor for the Multi-Level Lighting Switch installed is assumed to be consistent with the lighting loadshapes⁵¹¹. See Lighting Reference Table in

⁵⁰⁸ Assume ISR is 100%.

⁵⁰⁹ 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.

⁵¹⁰Negative value because this is an increase in heating consumption due to the efficient lighting.

⁵¹¹ 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

Section 3.4 for each building type. If the building type is unknown, use the Nonresidential Average value.

NATURAL GAS ENERGY SAVINGS

If gas heated building (or unknown):

$$\Delta Therms = KWControlled * Hours * ESF * (-IFTherms)$$

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.

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

= 197⁵¹²

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-LTG-MLLS-V01-170101

SUNSET DATE: 1/1/2019

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.

⁵¹² Number of days where HDD 55 >0.

3.5 Miscellaneous

3.5.1 Variable Frequency Drives for Process

DESCRIPTION

This measure applies to variable frequency drives (VFDs) installed on fans and pump motors in process applications. The VFD will modulate the speed of the motor when it does not need to run at full load. 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 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 savings⁵¹³.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years.⁵¹⁴

DEEMED MEASURE COST

Customer-provided costs will be used when available. Default measure costs⁵¹⁵ are listed below for 175 HP motors.

HP	Cost
1-9 HP	\$1,874
10-19 HP	\$2,967
20-29 HP	\$4,060
30-39 HP	\$5,154
40-49 HP	\$6,247
50-59 HP	\$7,340
60-69 HP	\$8,433
70-75 HP	\$9,526

LOADSHAPE

Custom Loadshape

⁵¹³ 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”.

⁵¹⁴ Efficiency Vermont TRM 10/26/11 for HVAC VFD motors.

⁵¹⁵ Average from IPL and MidAmerican VFD reported costs from rebate forms. IPL & MidA VFD Costs. xls

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = HP * Hours * SF$$

Where:

- HP = Nominal horsepower of controlled motor
= Actual
- HOURS = Annual operating hours of motor
= Actual
- SF = Savings factor⁵¹⁶
= 0.19 for process fans
= 0.26 for process pumps

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-MSV-VFDP-V01-170101

SUNSET DATE: 1/1/2018

⁵¹⁶ Savings factors derived from analysis of 16 MEC custom VFD projects. See 'Custom Process VFD Savings Factor.xlsx'.

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 program.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a commercial grade clothes washer meeting the minimum federal baseline as of January 2013⁵¹⁷.

Efficiency Level		Top loading	Front Loading
Baseline	Federal Standard	≥1.6 MEF, ≤8.5 WF	≥2.00 MEF, ≤5.5 WF
Efficient	ENERGY STAR	≥2.2 MEF, ≤4.5 WF	

The Modified Energy Factor (MEF) 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 Water Factor (WF) 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 cold wash, divided by the capacity of the clothes washer."*⁵¹⁸.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 11 years⁵¹⁹.

DEEMED MEASURE COST

The incremental cost is assumed to be \$200⁵²⁰:

LOADSHAPE

Loadshape RE01 - Residential Clothes Washer⁵²¹

Loadshape G01 - Flat (gas)

⁵¹⁷ See Federal Standard 10 CFR 431.152.

⁵¹⁸ Definitions provided on the Energy star website.

⁵¹⁹ Appliance Magazine, September 2007 as referenced in ENERGY STAR Commercial Clothes Washer Calculator.

⁵²⁰ Based on Industry Data 2007 as referenced in ENERGY STAR Commercial Clothes Washer Calculator.

⁵²¹ The Residential Clothes Washer loadshape is considered a reasonable proxy for commercial applications – in the absence of any other empirical basis.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

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

Where:

- Capacity = Clothes Washer capacity (cubic feet)
= Actual - If capacity is unknown, assume 3.1 cubic feet⁵²²
- MEFbase = Modified Energy Factor of baseline unit

Efficiency Level	MEFbase		
	Top loading	Front Loading	Weighted Average ⁵²³
Federal Standard	1.6	2.0	1.7

- MEFeff = Modified Energy Factor of efficient unit
= Actual. If unknown, assume average values provided below.

Efficiency Level	MEFeff		
	Top loading	Front Loading	Weighted Average
ENERGY STAR	2.2		

- Ncycles = Number of Cycles per year
= 2190⁵²⁴
- %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)

⁵²² Based on the average clothes washer volume of all units that pass the Federal Standard on the CEC database of commercial Clothes Washer products (accessed on 11/26/2015).

⁵²³ 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 CEC database (accessed 11/26/2015) and ENERGY STAR weighting is based on eligible products as of 11/26/2015. The relative weightings are as follows, see more information in "Commercial Clothes Washer Analysis.xlsx":

Efficiency Level	Front	Top
Baseline	37%	63%
ENERGY STAR	99%	1%

⁵²⁴ Based on DOE Technical Support Document, 2009; Chapter 8 Life-Cycle Cost and Payback Period Analysis, p 8-15.

efficient unit – see table below)

	Percentage of Total Energy Consumption ⁵²⁵		
	%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 below⁵²⁶:

Efficiency Level	ΔkWh			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	808.2	188.0	775.2	155.0

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 hours⁵²⁷
- CF = Summer Peak Coincidence Factor for measure
= 0.5⁵²⁸

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

⁵²⁵ 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).

⁵²⁶ 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.

⁵²⁷ Assuming an average load runs for an estimated 45 minutes.

⁵²⁸ 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	0.1845	0.0429	0.1770	0.0354

NATURAL GAS SAVINGS

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

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
= 1.26⁵²⁹

%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	26.7	1.1	27.8

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:

⁵²⁹ 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	0.0000	0.0731	0.0031	0.0761

WATER IMPACT DESCRIPTIONS AND CALCULATION

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

Where:

WFbase = Water Factor of baseline clothes washer

Efficiency Level	WFbase		
	Top loading	Front Loading	Weighted Average ⁵³⁰
Federal Standard	8.5	5.5	7.4

WFeff = 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	WF			$\Delta Water$ (gallons per year)
	Top Loaders	Front Loaders	Weighted Average	Weighted Average
Federal Standard	8.5	5.5	7.4	n/a
ENERGY STAR	4.5			19,874

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-MS-CLWA-V01-170101

⁵³⁰ 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 CEC database (accessed 11/26/2015) and ENERGY STAR weighting is based on eligible products as of 11/26/2015. The relative weightings are as follows, see more information in "Commercial Clothes Washer Analysis.xlsx":

Efficiency Level	Front	Top
Baseline	37%	63%
ENERGY STAR	99%	1%

SUNSET DATE: 1/1/2021

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 savings⁵³¹.

This measure applies to one-for-one replacement of old working or failed/near failure 1-350 horsepower⁵³² constant speed and uniformly loaded motors with new energy efficiency motors of the same rated horsepower that meet or 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 are at least 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 May 29, 2014⁵³³.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment efficiency is defined as the existing motor, when a new motor is purchased as an alternative to rewinding the existing model or a failed one.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years⁵³⁴.

DEEMED MEASURE COST

Use actual cost when available. If unknown default incremental measure cost assumed to be \$942.⁵³⁵

LOADSHAPE

Loadshape NRE03 – Non-Residential Industrial Motor

⁵³¹ Premium efficiency standards and sound motor management strategies as outlined by the Motor Decisions MatterSM (MDM) lead to reduced energy costs and increase productivity. For more information, go to www.motorsmatter.org

⁵³² 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>.

⁵³³ Motors covered by this new ruling include open and enclosed motor designs between 1-500 horsepower. The effective date of the rule is May 29, 2014 and compliance will be required for motors by June 1, 2016. Specifics can be found at under subpart B "Electric Motors" of Title 10 of the Code of Federal Regulations, Part 431 at <http://www.ecfr.gov>. Note According to EISA standards motors with a power rating of 1-200 HP shall have a nominal full-load efficiency that is not less than as defined in NEMA Premium efficiency levels. In addition motors previously meeting EAct (except fire pump motors) with a rating of greater than 200 but not more than 500 horse power are now required to meet the more stringent levels prescribed by NEMA Premium - MG 1-2011, Table 12-12. See <http://www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0027-0117> for more information.

⁵³⁴ Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Measure Life Study, KEMA, August 25, 2009.

⁵³⁵ This value is provided by IPL in their 2014-18 filing for Enhanced (Ultra-PE) Motor 125-200 HP, 1200-3600 RPM; Enhanced (Ultra-PE) Motor 250-500 HP, 1200-3600 RPM; Enhanced (Ultra-PE) Motor 50-100 HP, 1200-3600 RPM when using NEMA Qualifying Standard Motor as a base.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS⁵³⁶

$$\Delta kWh = (kW_{Base} - kW_{EE}) * Hours$$

$$kW_{Base} = \left(0.746 * HP * \frac{LF}{\eta_{Bmotor}} \right)$$

$$kW_{EE} = \left(0.746 * HP * \frac{LF}{\eta_{EEmotor}} \right)$$

Where:

- 0.746 = Conversion factor for HP to kWh
- HP = Nominal horsepower of controlled motor
- LF = Actual Load Factor; Motor Load at Fan/Pump Design CFM (Default = 75%)⁵³⁷
- η_{Bmotor} = Federal baseline nominal/nameplate motor efficiency as shown in table below for Open Drip Proof (ODP) and Totally Enclosed Fan Cooled (TEFC)⁵³⁸

⁵³⁶ 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.

⁵³⁷ 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.

⁵³⁸ For 1-200hp motors NEMA MG 1 Table 12-12. For over 201 HP NEMA MG 1 Table 12-11

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.5.3 Motors

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800	3600	1200	1800	3600
1	82.50%	85.50%	77.00%	82.50%	85.50%	77.00%
1.5	86.50%	86.50%	84.00%	87.50%	86.50%	84.00%
2	87.50%	86.50%	85.50%	88.50%	86.50%	85.50%
3	88.50%	89.50%	85.50%	89.50%	89.50%	86.50%
5	89.50%	89.50%	86.50%	89.50%	89.50%	88.50%
7.5	90.20%	91.00%	88.50%	91.00%	91.70%	89.50%
10	91.70%	91.70%	89.50%	91.00%	91.70%	90.20%
15	91.70%	93.00%	90.20%	91.70%	92.40%	91.00%
20	92.40%	93.00%	91.00%	91.70%	93.00%	91.00%
25	93.00%	93.60%	91.70%	93.00%	93.60%	91.70%
30	93.60%	94.10%	91.70%	93.00%	93.60%	91.70%
40	94.10%	94.10%	92.40%	94.10%	94.10%	92.40%
50	94.10%	94.50%	93.00%	94.10%	94.50%	93.00%
60	94.50%	95.00%	93.60%	94.50%	95.00%	93.60%
75	94.50%	95.00%	93.60%	94.50%	95.40%	93.60%
100	95.00%	95.40%	93.60%	95.00%	95.40%	94.10%
125	95.00%	95.40%	94.10%	95.00%	95.40%	95.00%
150	95.40%	95.80%	94.10%	95.80%	95.80%	95.00%
200	95.40%	95.80%	95.00%	95.80%	96.20%	95.40%
250	95.40%	95.80%	95.00%	95.80%	96.20%	95.80%
300	95.40%	95.80%	95.40%	95.80%	96.20%	95.80%
350	95.40%	95.80%	95.40%	95.80%	96.20%	95.80%

$\eta_{EE\text{motor}}$ =Efficient motor nominal/nameplate motor efficiency
 = Actual
 Hours = Hours for HVAC motors are found in table below⁵³⁹

Building Type	Hot Water Pump m Motor Hours	Chilled Water Pump Motor Hours	Fan Motor Run Hours
Convenience	3628	2690	4630
Education	3566	2833	1877
Grocery	2551	3994	4663
Health	3957	4369	3806
Hospital	4260	4647	6520
Industrial	3977	3080	2850
Lodging	5287	5292	3061
Multifamily	5287	5292	3061
Office - Large	5864	4608	2920
Office - Small	4482	2702	2920
Religious	4763	2223	2412
Restaurant	4127	2974	5443

⁵³⁹ All values taken from IA VFD Fan and pump measure including building type to ensure consistency across IA TRM. 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
Retail - Large	4218	2405	4065
Retail - Small	3985	2120	3694
Warehouse	4100	1788	2920
Nonresidential (average)	4253	3401	3656

For all non HVAC applications, hour of use are found below⁵⁴⁰

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (kW_{Base} - kW_{EE}) * CF$$

$$kW_{Base} = \left(0.746 * HP * \frac{LF}{\eta_{Bmotor}} \right)$$

$$kW_{EE} = \left(0.746 * HP * \frac{LF}{\eta_{EEmotor}} \right)$$

Where:

$$CF = 79.3\%^{541}$$

All other variables provided above.

NATURAL GAS ENERGY SAVINGS

There are no expected fossil fuel impacts for this measure⁵⁴².

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-V01-170101

SUNSET DATE: 1/1/2018

⁵⁴⁰ United States Industrial Electric Motor Systems Mark Opportunities Assessment (p. 66), December 2012: http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

⁵⁴¹ Industrial Motor CF in IA_Electric Loadshapes – Working Draft.xls

⁵⁴² Consider updating measure to include heating and cooling savings in future revisions.

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 2.0, Effective February 1, 2013)

Dishwasher Type	High Temp Efficiency Requirements		Low Temp Efficiency Requirements	
	Idle Energy Rate	Water Consumption	Idle Energy Rate	Water Consumption
Under Counter	≤ 0.50 kW	≤ 0.86 GPR	≤ 0.50 kW	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.70 kW	≤ 0.89 GPR	≤ 0.60 kW	≤ 1.18 GPR
Pot, Pan, and Utensil	≤ 1.20 kW	≤ 0.58 GPSF	≤ 1.00 kW	≤ 0.58 GPSF
Single Tank Conveyor	≤ 1.50 kW	≤ 0.70 GPR	≤ 1.50 kW	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 2.25 kW	≤ 0.54 GPR	≤ 2.00 kW	≤ 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:⁵⁴³

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

⁵⁴³ Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as “EPA/FSTC research on available models, 2013”

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

DEEMED MEASURE COST

The incremental capital cost for this measure is:⁵⁴⁴

Dishwasher Type		Incremental Cost
Low Temp	Under Counter	\$50
	Stationary Single Tank Door	\$0
	Single Tank Conveyor	\$0
	Multi Tank Conveyor	\$970
High Temp	Under Counter	\$120
	Stationary Single Tank Door	\$770
	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.

$$\Delta kWh^{545} = \Delta BuildingEnergy + \Delta BoosterEnergy^{546} + \Delta IdleEnergy$$

Where:

$$\begin{aligned} \Delta BuildingEnergy &= \text{Change in annual electric energy consumption of building water heater} \\ &= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] - \\ &\quad [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] \end{aligned}$$

$$\begin{aligned} \Delta BoosterEnergy &= \text{Annual electric energy consumption of booster water heater} \\ &= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] - \\ &\quad [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 3,412)] \end{aligned}$$

$$\begin{aligned} \Delta IdleEnergy &= \text{Annual idle electric energy consumption of dishwasher} \\ &= [IdleDraw_{Base} * (Hours * Days - Days * RacksWashed * WashTime \div 60)] - \\ &\quad [IdleDraw_{ESTAR} * (Hours * Days - Days * RacksWashed * WashTime \div 60)] \end{aligned}$$

Where:

$$WaterUse_{Base} = \text{Water use per rack (gal) of baseline dishwasher}$$

⁵⁴⁴ Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as “EPA research on available models using AutoQuotes, 2012”

⁵⁴⁵ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

⁵⁴⁶ Booster water heater energy only applies to high-temperature dishwashers.

	= Use value from table below as determined by machine type and sanitation method
WaterUse _{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 70 °F for building water heaters and 40 °F for booster water heaters
1.0	= Specific heat of water (Btu/lb/°F)
8.2	= Density of water (lb/gal)
Eff _{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
IdleDraw _{Base}	= Idle power draw (kW) of baseline dishwasher
	= Use value from table below as determined by machine type and sanitation method
IdleDraw _{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

EXAMPLE

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:

$$\Delta kWh = \Delta BuildingEnergy + \Delta BoosterEnergy + \Delta IdleEnergy$$

Where:

$$\begin{aligned} \Delta BuildingEnergy &= [(1.09 * 75 * 365.25) * (70 * 1.0 * 8.2 \div 0.98 \div 3,412)] - [(0.86 * 75 * 365.25) * (70 * 1.0 * 8.2 \div 0.98 \div 3,412)] \\ &= 1,082.7 \text{ kWh} \\ \Delta BoosterEnergy &= [(1.09 * 75 * 365.25) * (40 * 1.0 * 8.2 \div 0.98 \div 3,412)] - [(0.86 * 75 * 365.25) * (40 * 1.0 * 8.2 \div 0.98 \div 3,412)] \\ &= 618.7 \text{ kWh} \\ \Delta IdleEnergy &= [0.76 * (18 * 365.25 - 365.25 * 75 * 2.0 \div 60)] - \\ &\quad [0.50 * (18 * 365.25 - 365.25 * 75 * 2.0 \div 60)] \\ &= 1,472.0 \text{ Wh} \\ \Delta kWh &= 1,082.7 + 618.7 + 1,472.0 \\ &= 3,173.3 \text{ kWh} \end{aligned}$$

Default values for WaterUse, RacksWashed, kW_{Idle}, and WashTime are presented in the table below.

Low Temperature	RacksWashed	WashTime	WaterUse		IdleDraw	
	All Dishwashers	All Dishwashers	Conventional	ENERGY STAR	Conventional	ENERGY STAR
Under Counter	75	2.0	1.73	1.19	0.50	0.50
Stationary Single Tank Door	280	1.5	2.10	1.18	0.60	0.60
Single Tank Conveyor	400	0.3	1.31	0.79	1.60	1.50
Multi Tank Conveyor	600	0.3	1.04	0.54	2.00	2.00
High Temperature	All Dishwashers	All Dishwashers	Conventional	ENERGY STAR	Conventional	ENERGY STAR
Under Counter	75	2.0	1.09	0.86	0.76	0.50
Stationary Single Tank Door	280	1.0	1.29	0.89	0.87	0.70
Single Tank Conveyor	400	0.3	0.87	0.70	1.93	1.50
Multi Tank Conveyor	600	0.2	0.97	0.54	2.59	2.25
Pot, Pan, and Utensil	280	3.0	0.70	0.58	1.20	1.20

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	10,974.5	8,432.5	2,542.0
	Stationary Single Tank Door	39,316.7	23,148.3	16,168.4
	Single Tank Conveyor	42,239.4	28,599.8	13,639.6
	Multi Tank Conveyor	50,123.1	31,293.5	18,829.6

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
High Temp	Under Counter	12,365.8	9,192.4	3,173.3
	Stationary Single Tank Door	39,862.5	27,987.9	11,874.6
	Single Tank Conveyor	45,602.6	36,382.8	9,219.8
	Multi Tank Conveyor	72,539.4	45,105.5	27,433.8
	Pot, Pan, and Utensil	21,084.9	17,770.9	3,314.0

Electric building and natural gas booster water heating

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	10,974.5	8,432.5	2,542.0
	Stationary Single Tank Door	39,316.7	23,148.3	16,168.4
	Single Tank Conveyor	42,239.4	28,599.8	13,639.6
	Multi Tank Conveyor	50,123.1	31,293.5	18,829.6
High Temp	Under Counter	9,433.7	6,879.1	2,554.7
	Stationary Single Tank Door	26,907.7	19,050.1	7,857.6
	Single Tank Conveyor	33,121.3	26,340.3	6,781.0
	Multi Tank Conveyor	51,665.4	33,485.0	18,180.4
	Pot, Pan, and Utensil	14,055.2	11,946.3	2,108.9

Natural gas building and electric booster water heating

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	2,830.7	2,830.7	0.0
	Stationary Single Tank Door	2,410.7	2,410.7	0.0
	Single Tank Conveyor	9,350.4	8,766.0	584.4
	Multi Tank Conveyor	10,957.5	10,957.5	0.0
High Temp	Under Counter	7,234.7	5,144.0	2,090.6
	Stationary Single Tank Door	17,191.7	12,346.8	4,844.9
	Single Tank Conveyor	23,760.3	18,808.5	4,951.8
	Multi Tank Conveyor	36,009.9	24,769.6	11,240.4
	Pot, Pan, and Utensil	8,782.9	7,577.8	1,205.1

Natural gas building and natural gas booster water heating

Dishwasher type		kWh _{Base}	kWh _{ESTAR}	ΔkWh
Low Temp	Under Counter	2,830.7	2,830.7	0.0
	Stationary Single Tank Door	2,410.7	2,410.7	0.0
	Single Tank Conveyor	9,350.4	8,766.0	584.4
	Multi Tank Conveyor	10,957.5	10,957.5	0.0
High Temp	Under Counter	4,302.6	2,830.7	1,472.0
	Stationary Single Tank Door	4,236.9	3,409.0	827.9
	Single Tank Conveyor	11,278.9	8,766.0	2,512.9
	Multi Tank Conveyor	15,136.0	13,149.0	1,987.0
	Pot, Pan, and Utensil	1,753.2	1,753.2	0.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above
 CF = Summer peak coincidence factor
 = 0.638

Other variables as defined above.

EXAMPLE

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:

$$\begin{aligned} \Delta kW &= 3,173.3 / (18 * 365.25) * 0.638 \\ &= 0.3079 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms^{547} = \Delta BuildingEnergy + \Delta BoosterEnergy$$

Where:

$$\begin{aligned} \Delta BuildingEnergy &= \text{Change in annual natural gas consumption of building water heater} \\ &= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)] - \\ &\quad [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)] \end{aligned}$$

$$\begin{aligned} \Delta BoosterEnergy &= \text{Change in annual natural gas consumption of booster water heater} \\ &= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)] - \\ &\quad [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} * 1.0 * 8.2 \div Eff_{Heater} \div 100,000)] \end{aligned}$$

Where:

Eff_{Heater} = Efficiency of water heater
 = Custom or 80% for gas building and booster water heaters

100,000 = Therms to Btu conversion factor

Other variables as defined above.

⁵⁴⁷ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

EXAMPLE

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:

$$\Delta\text{Therms} = \Delta\text{BuildingEnergy} + \Delta\text{BoosterEnergy}$$

Where:

$$\begin{aligned} \Delta\text{BuildingEnergy} &= [(1.09 * 75 * 365.25) * (70 * 1.0 * 8.2 \div 0.80 \div 100,000)] - [(0.86 * 75 * 365.25) * (70 * 1.0 * 8.2 \div 0.80 \div 100,000)] \\ &= 45.3 \text{ therms} \\ \Delta\text{BoosterEnergy} &= [(1.09 * 75 * 365.25) * (40 * 1.0 * 8.2 \div 0.80 \div 100,000)] - [(0.86 * 75 * 365.25) * (40 * 1.0 * 8.2 \div 0.80 \div 100,000)] \\ &= 25.9 \text{ therms} \\ \Delta\text{Therms} &= 45.3 + 26.9 \\ &= 71.1 \text{ therms} \end{aligned}$$

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 _{SESTAR}	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 _{SESTAR}	ΔTherms
Low Temp	Under Counter	340.4	234.1	106.2
	Stationary Single Tank Door	1,542.6	866.8	675.8
	Single Tank Conveyor	1,374.7	829.0	545.7
	Multi Tank Conveyor	1,637.0	850.0	787.0
High Temp	Under Counter	337.0	265.9	71.1
	Stationary Single Tank Door	1,489.0	1,027.3	461.7
	Single Tank Conveyor	1,434.6	1,154.3	280.3
	Multi Tank Conveyor	2,399.3	1,335.7	1,063.6
	Pot, Pan, and Utensil	808.0	669.5	138.5

Natural gas building and electric booster water heating

Dishwasher type		Therms _{Base}	Therms _{SESTAR}	ΔTherms
Low	Under Counter	340.4	234.1	106.2

	Dishwasher type	Therms _{Base}	Therms _{ESTAR}	ΔTherms
Temp	Stationary Single Tank Door	1,542.6	866.8	675.8
	Single Tank Conveyor	1,374.7	829.0	545.7
	Multi Tank Conveyor	1,637.0	850.0	787.0
High Temp	Under Counter	214.5	169.2	45.3
	Stationary Single Tank Door	947.6	653.8	293.8
	Single Tank Conveyor	912.9	734.6	178.4
	Multi Tank Conveyor	1,526.8	850.0	676.8
	Pot, Pan, and Utensil	514.2	426.0	88.1

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

EXAMPLE

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:

$$\begin{aligned} \Delta PeakTherms &= 71.1 / 365.25 \\ &= 0.1947 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water = (WaterUse_{Base} * RacksWashed * Days) - (WaterUse_{ESTAR} * RacksWashed * Days)$$

Where:

WaterUse_{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

WaterUse_{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.

EXAMPLE

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:

$$\Delta\text{Water} = (\text{WaterUse}_{\text{Base}} * \text{RacksWashed} * \text{Days}) - (\text{WaterUse}_{\text{ESTAR}} * \text{RacksWashed} * \text{Days})$$

$$\begin{aligned} \Delta\text{Water} &= (1.73 * 75 * 365.25) - (1.19 * 75 * 365.25) \\ &= 14,792.6 \text{ gallons} \end{aligned}$$

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-V01-170101

SUNSET DATE: 1/1/2022

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 meeting energy consumptions requirements as determined by door type (solid or glass) and refrigerated volume (V).

ENERGY STAR Requirements (Version 3.0, Effective October 1, 2014)

Volume (ft ³)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
0 < V < 15	≤ 0.02V + 1.60	≤ 0.25V + 1.55
15 ≤ V < 30	≤ 0.09V + 0.55	≤ 0.20V + 2.30
30 ≤ V < 50	≤ 0.01V + 2.95	≤ 0.25V + 0.80
V ≥ 50	≤ 0.06V + 0.45	≤ 0.14V + 6.30
Glass Door		
0 < V < 15	≤ 0.10V + 1.07	≤ 0.56V + 1.61
15 ≤ V < 30	≤ 0.15V + 0.32	≤ 0.30V + 5.50
30 ≤ V < 50	≤ 0.06V + 3.02	≤ 0.55V – 2.00
V ≥ 50	≤ 0.08V + 2.02	≤ 0.32V + 9.49
Horizontal Closed		
Solid or Glass Doors		
All Volumes	≤ 0.06V + 0.60	≤ 0.10V + 0.20

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new vertical closed or horizontal closed, solid or glass door refrigerator or freezer that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.⁵⁴⁸

DEEMED MEASURE COST

The incremental capital cost for this measure is 0.⁵⁴⁹

⁵⁴⁸Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as “FSTC research on available models, 2009”

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

⁵⁴⁹ENERGY STAR Commercial Kitchen Equipment Savings Calculator

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below.⁵⁵⁰

$$\Delta kWh = (kWh_{Base} - kWh_{ESTAR}) * Days$$

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}^{551}
Solid Door Refrigerator	$0.10V + 2.04$
Glass Door Refrigerator	$0.12V + 3.34$
Solid Door Freezer	$0.40V + 1.38$
Glass Door Freezer	$0.75V + 4.10$

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)

Volume (ft ³)	Maximum Daily Energy Consumption (kWh/day)	
	Refrigerator	Freezer
Vertical Closed		
Solid Door		
$0 < V < 15$	$\leq 0.02V + 1.60$	$\leq 0.25V + 1.55$
$15 \leq V < 30$	$\leq 0.09V + 0.55$	$\leq 0.20V + 2.30$
$30 \leq V < 50$	$\leq 0.01V + 2.95$	$\leq 0.25V + 0.80$
$V \geq 50$	$\leq 0.06V + 0.45$	$\leq 0.14V + 6.30$
Glass Door		
$0 < V < 15$	$\leq 0.10V + 1.07$	$\leq 0.56V + 1.61$
$15 \leq V < 30$	$\leq 0.15V + 0.32$	$\leq 0.30V + 5.50$
$30 \leq V < 50$	$\leq 0.06V + 3.02$	$\leq 0.55V - 2.00$
$V \geq 50$	$\leq 0.08V + 2.02$	$\leq 0.32V + 9.49$
Horizontal Closed		
Solid or Glass Doors		
All Volumes	$\leq 0.06V + 0.60$	$\leq 0.10V + 0.20$

⁵⁵⁰ Algorithms and assumptions from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

⁵⁵¹10 CFR §431.66 - Energy Conservation Standards for Commercial Refrigerators, Freezers and Refrigerator-Freezers

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.6.2 Commercial Solid and Glass Door Refrigerator & Freezers

- 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
- = 365.25 days per year

EXAMPLE

For example, an ENERGY STAR solid door, vertical closed refrigerator with a volume of 35 ft³ would save:

$$\begin{aligned} \Delta kWh &= (kWh_{\text{Base}} - kWh_{\text{ESTAR}}) * \text{Days} \\ \Delta kWh &= [(0.10 * 35 + 2.04) - (0.01 * 35 + 2.95)] * 365.25 \\ &= 818.2 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh / \text{HOURS}) * CF$$

Where:

- ΔkWh = Electric energy savings, calculated above
- HOURS = Hours of refrigerator or freezer operation per year
- = 8766⁵⁵²
- CF = Summer peak coincidence factor
- = 0.964

EXAMPLE

For example, an ENERGY STAR solid door, vertical closed refrigerator with a volume of 35 ft³ would save:

$$\begin{aligned} \Delta kW &= (818.2 / 8766) * 0.964 \\ &= 0.0900 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

⁵⁵² Equipment is assumed to operate continuously, 24 hour per day, 365.25 days per year

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.6.2 Commercial Solid and Glass Door Refrigerator & Freezers

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-CSGD-V01-170101

SUNSET DATE: 1/1/2022

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 waste water (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 of 1.28 gallons per minute (gpm) or less.

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 1.60 gpm or less.⁵⁵³ For DI, the baseline equipment is an existing pre-rinse spray valve with a maximum flow rate of 2.23 gpm or less.⁵⁵⁴

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 5 years.⁵⁵⁵

DEEMED MEASURE COST

The cost of this measure is assumed to be \$0.⁵⁵⁶

LOADSHAPE

Loadshape NREW12 - Nonresidential Electric Hot Water – Restaurant

Loadshape NRGW12 - Nonresidential Gas Hot Water – Restaurant

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 1,285.4 kWh for TOS and 3,816.1 kWh for DI.⁵⁵⁷

⁵⁵³ 10 CFR 431.266, Energy Efficiency Program for Certain Commercial and Industrial Equipment

⁵⁵⁴ Verification measurements taken at 195 installations showed average pre-installation flow rate of 2.23 gpm. IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) (“CUWCC Report”, Feb 2007)

⁵⁵⁵ Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, which cites EPA research on average use, 2013

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

⁵⁵⁶ Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

⁵⁵⁷ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

$$\Delta kWh = HotPercentage * \Delta T_{in} * 1.0 * 8.2 / Eff_{Heater} / 3,412 * \Delta WaterUse$$

Where:

- HotPercentage = Percentage of hot water used for rinse
= Custom or If unknown, use 100%
- ΔT_{in} = Inlet water temperature increase (°F)
= Custom or if unknown, use 70 °F
- 1.0 = Specific heat of water (Btu/lb/°F)
- 8.2 = Density 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
- $\Delta WaterUse$ = Change in annual water consumption
= Custom calculation in Water Impact Descriptions and Calculation section of this measure, otherwise use 7,480.3 gal/yr for TOS and 22,207.2 gal/yr for DI

EXAMPLE

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above, would save:

$$\begin{aligned} \Delta kWh &= 1.00 * 70 * 1.0 * 8.2 / 0.98 / 3,412 * 7,480.3 \\ &= 1,285.4 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / ((Minutes/60) * Days) * CF$$

Where:

- ΔkWh = Electric energy savings, calculated above
- Minutes = Average daily minutes of spray valve operation
= Custom or if unknown, use 64 minutes per day⁵⁵⁸
- 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
= 0.0114 for a fast-food restaurant and 0.0250 for a sit-down restaurant⁵⁵⁹

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

⁵⁵⁸ ENERGY STAR Commercial Kitchen Equipment Savings Calculator

⁵⁵⁹ 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.

EXAMPLE

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:

$$\begin{aligned} \Delta kW &= 1,285.4 / ((64/60) * 365.25) * 0.0250 \\ &= 0.0825 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 53.7 therms/yr for TOS and 159.5 therms/yr for DI.⁵⁶⁰

$$\Delta Therms = HotPercentage * \Delta T_{in} * 1.0 * 8.2 / Eff_{Heater} / 100,000 * \Delta WaterUse$$

Where:

Eff_{Heater} = Efficiency of water heater
 = Custom or if unknown, use 80% for gas water heaters

100,000 = Btu to therms conversion factor

Other variables as defined above.

EXAMPLE

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned} \Delta Therms &= 1.00 * 70 * 1.0 * 8.2 / 0.80 / 100,000 * 7,480.3 \\ &= 53.7 \text{ therms/yr} \end{aligned}$$

PEAK GAS SAVINGS

$$\Delta PeakTherms = \Delta Therms / Days$$

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

EXAMPLE

For example, an efficient pre-rinse spray valve installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned} \Delta PeakTherms &= 53.7 / 365.25 \\ &= 0.1470 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below, otherwise use deemed value of 7,480.3 gal/yr for TOS and 22,207.2 gal/yr for DI.⁵⁶¹

$$\Delta WaterUse = (Flow_{Base} - Flow_{EE}) * Minutes * Days$$

⁵⁶⁰ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

⁵⁶¹ Algorithms and assumptions, except for DI baseline flow rate, derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

Where:

Flow_{Base} = Flow rate (gal/min) of baseline pre-rinse spray valve
 = Custom or if unknown, use 1.60 gpm⁵⁶² for TOS and 2.23 gpm⁵⁶³ for DI

Flow_{EE} = Flow rate (gal/min) of efficient pre-rinse spray valve
 = Custom or if unknown, use 1.28 gal/min

Other variables as defined above.

EXAMPLE

For example, an efficient pre-rinse spray valve, installed under the TOS program type, with defaults from the calculation above would save:

$$\begin{aligned} \Delta\text{WaterUse} &= (1.6 - 1.28) * 64 * 365.25 \\ &= 7,480.3 \text{ gal/yr} \end{aligned}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-SPRY-V01-170101

SUNSET DATE: 1/1/2022

⁵⁶² 10 CFR 431.266, Energy Efficiency Program for Certain Commercial and Industrial Equipment

⁵⁶³ IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2)

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.⁵⁶⁴

DEEMED MEASURE COST

The incremental capital cost for this measure is \$5,900.⁵⁶⁵

LOADSHAPE

Loadshape NRGC01 - 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:

⁵⁶⁴Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

⁵⁶⁵Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

InputRate _{Base}	= Rated energy input rate of baseline upright broiler (Btu/hr) = 95,000 Btu/hr ⁵⁶⁶
InputRate _{EE}	= Rated energy input rate of infrared upright broiler (Btu/hr) = Custom or if unknown, use 82,333 Btu/hr ⁵⁶⁷
Duty	= Duty cycle of upright broiler (%) = Custom or if unknown, use 70% ⁵⁶⁸
Hours	= Typical operating hours of upright broiler = Custom or if unknown, use 2,496 hours ⁵⁶⁹
100,000	= Btu to therms conversion factor
1,000	= Btu to Mbtu conversion factor

EXAMPLE

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 ⁵⁷⁰

EXAMPLE

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

⁵⁶⁶ Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Table 4.3
http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

⁵⁶⁷ 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%

⁵⁶⁸ Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

⁵⁶⁹ 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

⁵⁷⁰ 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

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IRUB-V01-170101

SUNSET DATE: 1/1/2022

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.⁵⁷¹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$1,000.⁵⁷²

LOADSHAPE

Loadshape NRGC01 - 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.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours) / 100,000}{InputRate_{EE} / 1,000}$$

⁵⁷¹Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

⁵⁷²Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

Where:

- InputRate_{Base} = Rated energy input rate of baseline salamander broiler (Btu/hr)
= 38,500 Btu/hr⁵⁷³
- InputRate_{EE} = Rated energy input rate of infrared salamander broiler (Btu/hr)
= Custom or if unknown, use 24,750 Btu/hr⁵⁷⁴
- Duty = Duty cycle of salamander broiler (%)
= Custom or if unknown, use 70%⁵⁷⁵
- Hours = Typical operating hours of salamander broiler
= Custom or if unknown, use 2,496 hours⁵⁷⁶
- 100,000 = Btu to therms conversion factor
- 1,000 = Btu to MBtu conversion factor

EXAMPLE

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 year⁵⁷⁷

EXAMPLE

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

⁵⁷³ Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Table 4.3

http://www.fishnick.com/equipment/techassessment/4_broilers.pdf

⁵⁷⁴ 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%

⁵⁷⁵ Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

⁵⁷⁶ 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

⁵⁷⁷ 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

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IRBL-V01-170101

SUNSET DATE: 1/1/2022

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.⁵⁷⁸

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,200.⁵⁷⁹

LOADSHAPE

Loadshape NRGC01 - 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.⁵⁸⁰

$$\Delta Therms = [(\Delta PreheatEnergy + \Delta CookingEnergy) * Days / 100,000] / \left(\frac{InputRate_{EE}}{1,000} \right)$$

⁵⁷⁸Measure life from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator, <http://www.fishnick.com/saveenergy/tools/calculators/gbroilercalc.php>

⁵⁷⁹Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562

⁵⁸⁰ 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

Where:

$$\Delta\text{PreheatEnergy} = (\text{PreheatRate}_{\text{Base}} * \text{Preheats} * \text{PreheatTime} / 60) - (\text{PreheatRate}_{\text{EE}} * \text{Preheats} * \text{PreheatTime} / 60)$$

$$\Delta\text{CookingEnergy} = (\text{InputRate}_{\text{Base}} - \text{InputRate}_{\text{EE}}) * \text{Hours}$$

Where:

- Days = Annual days of operation
= Custom or if unknown, use 312 days per year⁵⁸¹
- 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 preheat⁵⁸²
- 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

⁵⁸¹Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3

⁵⁸²Typical preheat time from FSTC Broiler Technology Assessment

EXAMPLE

For example, an infrared charbroiler with default values from the calculation above would save:

$$\Delta\text{Therms} = [(\Delta\text{PreheatEnergy} + \Delta\text{CookingEnergy}) * \text{Days} / 100,000] / (\text{InputRate}_{EE} / 1,000)$$

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

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

Where:

ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

EXAMPLE

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

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 2.1, Effective January 1, 2014)

Oven Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency Consumption	Idle Energy Rate	Cooking Efficiency Consumption
Full Size	≤ 1.60 kW	≥ 71%	≤ 12,000 Btu/hr	≥ 46%
Half Size	≤ 1.00 kW		N/A	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.⁵⁸³

DEEMED MEASURE COST

The incremental capital cost for this measure is \$400.⁵⁸⁴

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 convection oven below, otherwise use deemed value of 1,938.5 kWh for full-size

⁵⁸³ Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009”

https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

⁵⁸⁴Measure cost from 2014-2023 Iowa Statewide Assessment of Energy Efficiency Potential

ovens and 192.1 kWh for half-size ovens.⁵⁸⁵

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

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 1,600 for full-size ovens and 1,000 for half-size ovens
- 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 both full-size and half-size ovens

⁵⁸⁵ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

EXAMPLE

For example, an ENERGY STAR full-size electric convection oven with default values from the algorithm above would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= (2,000 * (12 - 100 / 90)) - (1,600 * (12 - 100 / 90)) \\ &= 4,356 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 73.2 / 0.65) - (100 * 73.2 / 0.71) \\ &= 952 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (4,356 + 952) * 365.25 / 1,000 \\ &= 1,938.5 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

$$\Delta kWh = \text{Electric energy savings, calculated above}$$

$$CF = \text{Summer peak coincidence factor}$$

$$= 0.787$$

Other variables as defined above.

EXAMPLE

For example, an ENERGY STAR full-size electric convection oven with default values from the algorithm above would save:

$$\begin{aligned} \Delta kW &= 1,938.5 / (12 * 365.25) * 0.787 \\ &= 0.3481 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas convection oven below, otherwise use deemed value of 129.4 therms/yr.⁵⁸⁶

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

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:

⁵⁸⁶ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

- 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
- 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 12,000 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 46%

Other variables as defined above.

EXAMPLE

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:

$$\begin{aligned} \Delta\text{IdleEnergy} &= (15,100 * (12 - 100 / 83)) - (12,000 * (12 - 100 / 86)) \\ &= 32,960 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (100 * 250 / 0.44) - (100 * 250 / 0.46) \\ &= 2,470 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= (32,960 + 2,470) * 365.25 / 100,000 \\ &= 129.4 \text{ therms/yr} \end{aligned}$$

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.

EXAMPLE

For example, an ENERGY STAR gas convection with default values from the algorithm above would save:

$$\begin{aligned}\Delta\text{PeakTherms} &= 129.4 / 365.25 \\ &= 0.3543 \text{ therms/day}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-ESCV-V01-170101

SUNSET DATE: 1/1/2022

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.⁵⁸⁷

DEEMED MEASURE COST

The incremental capital cost for this measure is \$1800.⁵⁸⁸

LOADSHAPE

Loadshape NRGC01 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

⁵⁸⁷Measure life from Food Service Technology Center Gas Conveyor Oven Life-Cycle Cost Calculator <http://www.fishnick.com/saveenergy/tools/calculators/gconvovencalc.php>

⁵⁸⁸Nicor 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 594.1 therms/yr.⁵⁸⁹

$$\Delta Therms = (\Delta PreheatEnergy + \Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\Delta PreheatEnergy = (PreheatRate_{Base} * Preheats * PreheatTime / 60) - (PreheatRate_{EE} * Preheats * PreheatTime / 60)$$

$$\Delta IdleEnergy = IdleRate_{Base} * (Hours - (FoodCooked / Production_{Base})) - (Preheats * PreheatTime / 60) - IdleRate_{ESTAR} * (Hours - (FoodCooked / Production_{ESTAR})) - (Preheats * PreheatTime / 60)$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

- Days = Annual days of operation
= Custom or if unknown, use 312 days per year
- 100,000 = Btu to therms conversion factor
- PreheatRate_{Base} = Preheat energy rate of baseline oven
= 35,000 Btu/hr
- PreheatRate_{EE} = Preheat energy rate of efficient oven
= Custom or if unknown, use 18,000 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 preheat⁵⁹⁰
- 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 day
- 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
- Production_{EE} = Production capacity of efficient oven

⁵⁸⁹ Assumptions derived from Food Service Technology Center Gas Conveyor Oven Life-Cycle Cost Calculator and from FSTC Oven Technology Assessment, http://www.fishnick.com/equipment/techassessment/7_ovens.pdf.

⁵⁹⁰ Engineering assumption

- = Custom or if unknown, use 220 pizzas per hour
- EFOOD = ASTM energy to food
- = 170 Btu/pizza
- Eff_{Base} = Cooking efficiency of baseline oven
- = 20%
- Eff_{EE} = Cooking efficiency of efficient oven
- = Custom or if unknown, use 42%

EXAMPLE

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:

$$\begin{aligned} \Delta\text{PreheatEnergy} &= (35,000 * 1 * 15 / 60) - (18,000 * 1 * 15 / 60) \\ &= 4,250 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{IdleEnergy} &= 70,000 * (10 - (250 / 150) - (1 * 15 / 60)) - 57,000 * (10 - (250 / 220) - (1 * 15 / 60)) \\ &= 74,856 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (250 * 170 / 0.20) - (250 * 170 / 0.42) \\ &= 111,310 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= (4,250 + 74,856 + 111,310) * 312 / 100,000 \\ &= 594.1 \text{ therms/yr} \end{aligned}$$

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

EXAMPLE

For example, an efficient conveyor oven with default values from the algorithm above would save:

$$\begin{aligned} \Delta\text{PeakTherms} &= 594.1 / 312 \\ &= 1.9042 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-CVOV-V01-170101

SUNSET DATE: 1/1/2022

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.⁵⁹¹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$2,700.⁵⁹²

LOADSHAPE

Loadshape NRGC01 - 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.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours) / 100,000}{InputRate_{EE} / 1,000}$$

⁵⁹¹Measure life from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

⁵⁹²Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

Where:

- InputRate_{Base} = Energy input rate of baseline rotisserie oven (Btu/hr)
= 50,000 Btu/hr⁵⁹³
- InputRate_{EE} = Energy input rate of infrared rotisserie oven (Btu/hr)
= Custom or if unknown, use 40,323 Btu/hr⁵⁹⁴
- Duty = Duty cycle of rotisserie oven (%)
= Custom or if unknown, use 60%⁵⁹⁵
- Hours = Typical operating hours of rotisserie oven
= Custom or if unknown, use 2,496 hours⁵⁹⁶
- 100,000 = Btu to therms conversion factor
- 1,000 = Btu to MBtu conversion factor

EXAMPLE

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 year⁵⁹⁷

EXAMPLE

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

⁵⁹³ Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Table 7.2

http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

⁵⁹⁴ 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%

⁵⁹⁵ Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7.2

⁵⁹⁶ 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

⁵⁹⁷ 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

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-IROV-V01-170101

SUNSET DATE: 1/1/2022

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.⁵⁹⁸

DEEMED MEASURE COST

The incremental capital cost⁵⁹⁹ for this measure, listed in the table below, depends on fuel type and pan capacity:

Pan Capacity	Electric Steam Cooker Costs	Natural Gas Steam Cooker Costs
3-pan	\$630	\$260
4-pan	\$1,210	N/A ⁶⁰⁰
5-pan	\$0	\$0
6-pan and larger	\$0	\$870

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRG01 - Nonresidential Gas Cooking – Restaurant

⁵⁹⁸Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

⁵⁹⁹Incremental costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator. Calculator cites EPA research using AutoQuotes, 2012.

⁶⁰⁰ Although Version 1.2 of the ENERGY STAR specification provides an idle energy rate requirement for 4-pan gas units, currently there are no 4-pan gas units available. These units were excluded from this measure characterization.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric steam cooker below, otherwise use deemed value from the table that follows.⁶⁰¹

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

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 capacity⁶⁰²
- 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

⁶⁰¹ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

⁶⁰² 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 cooker⁶⁰³
= 28%
- 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 12 hours per day
- FoodCooked = Food cooked per day (lbs)
= Custom or if unknown, use 100 pounds

EXAMPLE

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:

$$\begin{aligned} \Delta IdleEnergy &= [(1 - 0.40) * 1,100 + 0.40 * 23.3 * 6 * 30.8 / 0.28] * (12 - 100 / (23.3 * 6)) - [(1 - 0.40) * 800 + 0.40 * 16.7 * 6 * 30.8 / 0.50] * (12 - 100 / (16.7 * 6)) \\ &= 44,418 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 30.8 / 0.28) - (100 * 30.8 / 0.50) \\ &= 4,840 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (44,418 + 4,840) * 365.25 / 1,000 \\ &= 17,991.6 \text{ kWh} \end{aligned}$$

Savings for all pan capacities are presented in the table below.

Energy Consumption of Electric Steam Cookers			
Pan Capacity	kWh _{Base}	kWh _{ESTAR}	Savings (kWh)
3	18,438.9	7,637.6	10,801.3
4	23,018.6	9,784.1	13,234.5
5	27,563.8	11,953.8	15,609.9
6	32,091.7	14,100.1	17,991.6
10	50,134.5	21,384.3	28,750.1
Average	30,249.5	12,972.0	17,277.5

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

⁶⁰³ Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR for steam generator and boiler-based cookers

ΔkWh = Electric energy savings, calculated above
 CF = Summer peak coincidence factor
 = 0.787

Other variables as defined above

EXAMPLE

For example, an ENERGY STAR, 6-pan electric steam cooker with defaults from the calculation above would save:

$$\Delta kW = 17,991.6 / (12 * 365.25) * 0.787$$

$$= 3.2305 \text{ kW}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas steam cooker below, otherwise use deemed value from the table that follows.⁶⁰⁴

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

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:

- 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 capacity⁶⁰⁵
- 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

⁶⁰⁴ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

⁶⁰⁵ Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR for steam generator and boiler-based cookers

- EFOOD = ASTM energy to food
= 105 Btu/lb
- Eff_{Base} = Cooking efficiency (%) of baseline gas steam cooker⁶⁰⁶
= 16.5%
- Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR gas steam cooker
= Custom or if unknown, use 38%

Other variables as defined above.

EXAMPLE

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:

$$\begin{aligned} \Delta\text{IdleEnergy} &= [(1 - 0.40) * 16,500 + 0.40 * 23.3 * 6 * 105 / 0.165] * (12 - 100 / (23.3 * 6)) - [(1 - 0.40) * 12,500 + 0.40 * 20 * 6 * 105 / 0.38] * (12 - 100 / (20 * 6)) \\ &= 281,434 \text{ Btu} \\ \Delta\text{CookingEnergy} &= (100 * 105 / 0.17) - (100 * 105 / 0.38) \\ &= 36,005 \text{ Btu} \\ \Delta\text{Therms} &= (281,434 + 36,005) * 365.25 / 100,000 \\ &= 1,159.4 \text{ therms} \end{aligned}$$

Savings for all pan capacities are presented in the table below.

Energy Consumption of Gas Steam Cookers			
Pan Capacity	Therms _{Base}	Therms _{ESTAR}	Savings (Therms)
3	1,301.5	492.8	808.7
5	1,842.1	795.7	1,046.4
6	2,107.2	947.8	1,159.4
10	3,157.4	1,344.5	1,812.9
Average	1,996.0	845.0	1,150.0

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

⁶⁰⁶ Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR for steam generator and boiler-based cookers

EXAMPLE

For example, an ENERGY STAR, 6-pan gas steam cooker with defaults from the calculation above would save:

$$\begin{aligned} \Delta\text{PeakTherms} &= 1,159.4 / 365.25 \\ &= 3.1743 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below, otherwise use deemed value of 134,412.0 gallons per year.⁶⁰⁷ Savings are the same for electric and gas steam cookers.

$$\Delta\text{Water} = (\Delta\text{WaterUse}_{\text{Base}} - \Delta\text{WaterUse}_{\text{ESTAR}}) * \text{Hours} * \text{Days}$$

Where:

$$\begin{aligned} \text{WaterUse}_{\text{Base}} &= \text{Water use (gal/hr) of baseline steam cooker} \\ &= 40 \text{ gal/hr} \end{aligned}$$

$$\begin{aligned} \text{WaterUse}_{\text{ESTAR}} &= \text{Water use (gal/hr) of ENERGY STAR steam cooker}^{608} \\ &= \text{Custom or if unknown, use 9.3 gal/hr} \end{aligned}$$

Other variables as defined above

EXAMPLE

For example, a steam cooker with defaults from the calculation above would save

$$\begin{aligned} \Delta\text{WaterUse} &= (40 - 9.3) * 12 * 365.25 \\ &= 134,412.0 \text{ gal/year} \end{aligned}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-STMC-V01-170101

SUNSET DATE: 1/1/2022

⁶⁰⁷ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

⁶⁰⁸ Water use for ENERGY STAR steam cookers is the average of water use values provided by ENERGY STAR for steam generator and boiler-based 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 2.0, Effective April 22, 2011)

Fryer Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
Standard Open Deep-Fat Fryer	≤ 1,000 W	≥ 80%	≤ 9,000 Btu/hr	≥ 50%
Large Vat Open Deep-Fat Fryer	≤ 1,100 W		≤ 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.⁶⁰⁹

DEEMED MEASURE COST

The incremental capital cost for this measure is \$210 for standard electric, \$0 for large vat electric, \$0 for standard gas, and \$1,120 for large vat gas fryers.⁶¹⁰

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRG01 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

⁶⁰⁹Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009”

https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

⁶¹⁰ Measure costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, which cites reference as “EPA research on available models using AutoQuotes, 2012”

Custom calculation for an electric fryer below, otherwise use deemed value of 952.3 kWh for standard fryers and 2,537.9 kWh for large vat fryers.⁶¹¹

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

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
= 1,050 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 1,000 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 80% for both standard and large vat fryers

⁶¹¹ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

EXAMPLE

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:

$$\begin{aligned} \Delta IdleEnergy &= (1,050 * (16 - 150 / 65)) - (1,000 * (16 - 150 / 70)) \\ &= 520 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta CookingEnergy &= (150 * 167 / 0.75) - (150 * 167 / 0.80) \\ &= 2,088 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (520 + 2,088) * 365.25 / 1,000 \\ &= 952.3 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
= 0.787

Other variables as defined above.

EXAMPLE

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

$$\begin{aligned} \Delta kW &= 952.3 / (16 * 365.25) * 0.787 \\ &= 0.1282 \text{ kW} \end{aligned}$$

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.⁶¹²

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\Delta IdleEnergy = (IdleRate_{Base} * (Hours - FoodCooked/Production_{Base})) - (IdleRate_{ESTAR} * (Hours - FoodCooked/Production_{ESTAR}))$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

⁶¹² Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

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
= 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
- EFOOD = 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.

EXAMPLE

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:

- ΔTherms = Natural gas energy savings, calculated above

Other variables as defined above.

EXAMPLE

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-V01-170101

SUNSET DATE: 1/1/2022

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.⁶¹³

DEEMED MEASURE COST

The incremental capital cost for this measure is \$0 for an electric griddle and \$360 for a gas griddle.⁶¹⁴

LOADSHAPE

Loadshape NRE02 - Nonresidential Electric Cooking – Restaurant

Loadshape NRGC01 - Nonresidential Gas Cooking – Restaurant

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric griddle below, otherwise use deemed value of 1,910.4 kWh.⁶¹⁵

⁶¹³ Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009”

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

⁶¹⁴ Measure cost from Commercial Kitchen Equipment Savings Calculator, which cites reference as “EPA research on available models using AutoQuotes, 2012”

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

⁶¹⁵ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [(IdleRate_{Base} * Width * Length) * (Hours - FoodCooked/Production_{Base})] - [(IdleRate_{ESTAR} * Width * Length) * (Hours - FoodCooked/Production_{ESTAR})]$$

$$\Delta CookingEnergy = (FoodCooked * EFOOD / Eff_{Base}) - (FoodCooked * EFOOD / Eff_{ESTAR})$$

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
- 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
- Production_{ESTAR} = Production capacity of ENERGY STAR electric griddle
= Custom or if unknown, use 40 lb/hr
- 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
- EFOOD = ASTM energy to food
= 139 Wh/lb
- Eff_{Base} = Cooking efficiency of baseline electric griddle
= 65%
- Eff_{ESTAR} = Cooking efficiency of ENERGY STAR electric griddle
= Custom or if unknown, use 70%

EXAMPLE

For example, an ENERGY STAR electric griddle with defaults from the calculation above would save:

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 1,000$$

Where:

$$\Delta IdleEnergy = [400 * (3 * 2) * (12 - 100 / 35)] - [320 * (3 * 2) * (12 - 100 / 40)] = 3,703 \text{ Wh}$$

$$\begin{aligned} \Delta CookingEnergy &= (100 * 139 / 0.65) - (100 * 139 / 0.70) \\ &= 1,528 \text{ Wh} \end{aligned}$$

$$\begin{aligned} \Delta kWh &= (3,703 + 1,528) * 365.25 / 1,000 \\ &= 1,910.4 \text{ kWh} \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

Where:

$$\Delta kWh = \text{Electric energy savings, calculated above}$$

$$\begin{aligned} CF &= \text{Summer peak coincidence factor} \\ &= 0.787 \end{aligned}$$

Other variables as defined above.

EXAMPLE

For example, an ENERGY STAR electric griddle with defaults from the calculation above would save:

$$\begin{aligned} \Delta kW &= 1,910.4 / (12 * 365.25) * 0.787 \\ &= 0.3430 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas griddle below, otherwise use deemed value of 131.4 therms.⁶¹⁶

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days / 100,000$$

Where:

$$\begin{aligned} \Delta IdleEnergy &= [IdleRate_{Base} * (Width * Length) * (Hours - FoodCooked/Production_{Base})] - [IdleRate_{ESTAR} \\ &\quad * (Width * Length) * (Hours - FoodCooked/Production_{ESTAR})] \end{aligned}$$

$$\Delta CookingEnergy = (FoodCooked * E_{FOOD} / Eff_{Base}) - (FoodCooked * E_{FOOD} / Eff_{ESTAR})$$

Where:

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

$$\begin{aligned} Production_{Base} &= \text{Production capacity of baseline gas griddle} \\ &= 25 \text{ lb/hr} \end{aligned}$$

$$Production_{ESTAR} = \text{Production capacity of ENERGY STAR gas griddle}$$

⁶¹⁶ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

- = Custom or if unknown, use 45 lb/hr
- IdleRate_{Base} = Idle energy rate of baseline gas griddle
= 3,500 Btu/hr/ft²
- IdleRate_{ESTAR} = Idle energy rate of ENERGY STAR gas griddle
= Custom or if unknown, use 2,650 Btu/hr/ft²
- E_{FOOD} = ASTM energy to food
= 475 Btu/lb
- Eff_{Base} = Cooking efficiency of baseline gas griddle
= 32%
- Eff_{ESTAR} = Cooking efficiency of ENERGY STAR gas griddle
= Custom or if unknown, use 38%

Other variables as defined above.

EXAMPLE

For example, an ENERGY STAR gas griddle with defaults from the calculation above would save:

$$\Delta\text{Therms} = (\Delta\text{IdleEnergy} + \Delta\text{CookingEnergy}) * \text{Days} / 100,000$$

Where:

$$\begin{aligned} \Delta\text{IdleEnergy} &= [3,500 * (3 * 2) * (12 - 100 / 25)] - [2,650 * (3 * 2) * (12 - 100 / 45)] \\ &= 12,533 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{CookingEnergy} &= (100 * 475 / 0.32) - (100 * 475 / 0.38) \\ &= 23,438 \text{ Btu/day} \end{aligned}$$

$$\begin{aligned} \Delta\text{Therms} &= (12,533 + 23,438) * 365.25 / 100,000 \\ &= 131.4 \text{ therms/yr} \end{aligned}$$

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.

EXAMPLE

For example, an ENERGY STAR gas griddle with defaults from the calculation above would save:

$$\begin{aligned} \Delta\text{PeakTherms} &= 131.4 / 365.25 \\ &= 0.3598 \text{ therms/day} \end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-FSE-ESGR-V01-170101

SUNSET DATE: 1/1/2022

3.7 Shell

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 inspectors⁶¹⁷. Where this occurs, an algorithm is provided to estimate the site specific savings. Where test in/test out has not occurred, a conservative deemed assumption is provided.

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

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

DEFINITION OF EFFICIENT EQUIPMENT

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be assessed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

DEFINITION OF BASELINE EQUIPMENT

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly affects the opportunity for cost-effective energy savings through air-sealing.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.⁶¹⁸

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)

NREP01:16 – Nonresidential Electric Heat Pump (by Building Type)

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

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

⁶¹⁷ Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.

⁶¹⁸ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

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} = Infiltration at natural conditions as estimated by blower door testing before air sealing
= Actual⁶¹⁹

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

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 75°F indoor air temperature

Climate Zone (City based upon)	OA _{AVG,cooling} [°F] ⁶²⁰	ΔT _{AVG,cooling} [°F]
Burlington	80.4	5.4
Des Moines	78.6	3.6
Mason City	75.2	0.2

0.018 = Specific Heat Capacity of Air (Btu/ft³*°F)

LM = Latent multiplier to account for latent cooling demand
= dependent on location: ⁶²¹

Climate Zone (City based upon)	LM
Zone 5 (Burlington)	4.1
Zone 6 (Mason City)	4.2
Average/ unknown (Des Moines)	4.2

⁶¹⁹ 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.

⁶²⁰ 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.

⁶²¹ 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..

- 1000 = Converts Btu to kWh
- $\eta_{cooling}$ = 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
- $\Delta kWh_{heating}$ = 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 55°F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ⁶²²	$\Delta T_{AVG,heating}$ [°F]
Burlington	39.6	15.4
Des Moines	35.9	19.1
Mason City	30.1	24.9

- 3,142 = Conversion from Btu to kWh.
- $\eta_{heating}$ = Efficiency of heating system, expressed as COP
 = Actual. For equipment with HSPF ratings, use the following conversion to COP:
 COP = HSPF/3.413

For example, a small retail building (2,000 Sq) Ft in Des Moines with 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned} \Delta kWh &= \Delta kWh_{cooling} + \Delta kWh_{heating} \\ &= [((340 - 225) * 60 * 1039 * 3.6 * 0.018 * 4.2) / (1000 * 10.5)] + \\ &\quad [((340 - 225) * 60 * 1608 * 19.1 * 0.018) / (1.92 * 3,412)] \\ &= 186 + 582 \\ &= 768 \text{ kWh} \end{aligned}$$

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

⁶²² 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.

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment⁶²³

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%⁶²⁴

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:

$$\Delta kWh = 28 * 0.0314 * 29.3 = 25 \text{ kWh}$$

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)

⁶²³ 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.

⁶²⁴ F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (E_f in MMBtu/yr) and E_{ae} (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% F_e . See "Furnace Fan Analysis.xlsx" for reference.

Building Type	CF ⁶²⁵
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ⁶²⁶	79.8%

For example, a small retail building (2,000 Sq) Ft in Des Moines with 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), with pre- and post-sealing natural infiltration rates of 340 and 225 CFM, respectively:

$$\begin{aligned} \Delta kW &= 186 / 1039 * 0.877 \\ &= 0.1570 \text{ kW} \end{aligned}$$

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 = 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:

$$\begin{aligned} \Delta Therms &= ((340 - 225) * 60 * 1036 * 15.4 * 0.018) / (0.70 * 100,000) \\ &= 28 \text{ therms} \end{aligned}$$

⁶²⁵ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁶²⁶ For weighting factors, see HVAC variable table in section 3.3.

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment⁶²⁷

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 ⁶²⁸
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ⁶²⁹	0.012386

⁶²⁷ 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.

⁶²⁸ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

⁶²⁹ For weighting factors, see HVAC variable table in section 3.3.

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:

$$\begin{aligned}\Delta\text{PeakTherms} &= 28 * 0.013452 \\ &= 0.3767 \text{ therms}\end{aligned}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-AIRS-V01-170101

SUNSET DATE: 1/1/2020

3.7.2 Foundation Wall Insulation

DESCRIPTION

Energy and demand saving 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 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.

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

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}} \right) * Area_{AG} * CRF * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $R_{existingAG}$ = Above grade wall heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
- R_{newAG} = Above grade wall heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- $Area_{AG}$ = Area of the above grade wall surface in square feet.
- CRF = Correction Factor. Adjustment to account for the effects the framing has on the overall assembly R-value, when cavity insulation is used.
 - = 100% if Spray Foam or External Rigid Foam
 - = 50% if studs and cavity insulation⁶³⁰
- $EFLH_{cooling}$ = 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 ΔT between outdoor air temperature and assumed 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁶³¹	$\Delta T_{AVG,cooling}$ [°F]
Burlington	80.4	5.4
Des Moines	78.6	3.6
Mason City	75.2	0.2

- 1,000 = Conversion from Btu to kWh
- $\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kWh/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:

$$\Delta kWh_{heating} = \frac{\left(\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}} \right) * Area_{AG} \right) + \left(\left(\frac{1}{R_{existingBG}} - \frac{1}{R_{newBG}} \right) * Area_{BG} \right) * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

Where:

- $R_{existingBG}$ = Below grade wall assembly heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]

⁶³⁰ Consistent with the information listed in ASHRAE, 2001, Table 5-1 Wall Sections with Steel Studs Parallel Path Correction Factors and experimental findings by the Oak Ridge National Laboratory, "Couple Secrets about How Framing is Effecting the Thermal Performance of Wood and Steel-Framed Walls."

⁶³¹ 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 below

For example, for an area that extends 5 feet below grade, an R-value of 7.46 would be selected and added to the existing insulation R-value.

Below Grade R-value									
Depth below grade (ft)	0	1	2	3	4	5	6	7	8
Earth R-value (°F-ft ² -h/Btu)	2.44	4.50	6.30	8.40	10.44	12.66	14.49	17.00	20.00
Average Earth R-value (°F-ft ² -h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69

R_{newBG} = Below grade wall assembly heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]

$Area_{BG}$ = Area of the below grade wall surface in square feet.

$EFLH_{heating}$ = 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 55°F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ⁶³²	$\Delta T_{AVG,heating}$ [°F]
Burlington	39.6	15.4
Des Moines	35.9	19.1
Mason City	30.1	24.9

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%

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%⁶³³

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

⁶³² 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.

⁶³³ 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.

$$\Delta kW = (\Delta kWh_{cooling} / EFLH_{cooling}) * CF$$

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 ⁶³⁴
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ⁶³⁵	79.8%

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

ΔTherms

$$= \frac{\left(\left(\left(\frac{1}{R_{existingAG}} - \frac{1}{R_{newAG}} \right) * Area_{AG} \right) + \left(\left(\frac{1}{R_{existingBG}} - \frac{1}{R_{newBG}} \right) * Area_{BG} \right) \right) * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(100,000 * \eta_{heat})}$$

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:

⁶³⁴ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁶³⁵ For weighting factors, see HVAC variable table in section 3.3.

Δ Therms = Therm impact calculated above

GCF = Gas Coincidence Factor for Heating

Building Type	GCF ⁶³⁶
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ⁶³⁷	0.012386

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-FINS-V01-170101

SUNSET DATE: 1/1/2020

⁶³⁶ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

⁶³⁷ For weighting factors, see HVAC variable table in section 3.3.

3.7.3 Roof 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 above code and should be determined by the program.

DEFINITION OF BASELINE EQUIPMENT

For retrofit projects, the baseline condition is the existing condition. It should be based on the entire wall assembly. If existing condition is unknown, assume IECC 2006. For NC 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

Per the 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”, the material cost for R-30 insulation is \$0.75 per square foot. The installation cost is \$0.61 per square foot. The total measure cost, therefore, is \$1.36 per square foot of insulation installed. However, the actual cost should be used when available.

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

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * CRF * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $R_{existing}$ = Roof assembly heat loss coefficient with existing insulation (or code baseline for NC) [(hr-°F-ft²)/Btu]
- R_{new} = Roof assembly heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- Area = Area of the roof surface in square feet.
- CRF = Correction Factor. Adjustment to account for the effects the framing has on the overall assembly R-value, when cavity insulation is used.
 - = 100% if Spray Foam or External Rigid Foam
 - = 50% if studs and cavity insulation⁶³⁸
- $EFLH_{cooling}$ = 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 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁶³⁹	$\Delta T_{AVG,cooling}$ [°F]
Burlington	80.4	5.4
Des Moines	78.6	3.6
Mason City	75.2	0.2

- 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:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

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 55°F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ⁶⁴⁰	$\Delta T_{AVG,heating}$ [°F]
Burlington	39.6	15.4

⁶³⁸ Consistent with the information listed in ASHRAE, 2001, Table 5-1 Wall Sections with Steel Studs Parallel Path Correction Factors and experimental findings by the Oak Ridge National Laboratory, "Couple Secrets about How Framing is Effecting the Thermal Performance of Wood and Steel-Framed Walls."

⁶³⁹ 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.

⁶⁴⁰ National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3

Climate Zone (City based upon)	OA _{AVG,heating} [°F] ⁶⁴⁰	ΔT _{AVG,heating} [°F]
Des Moines	35.9	19.1
Mason City	30.1	24.9

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%*

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%⁶⁴¹

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh_{\text{cooling}}}{EFLH_{\text{cooling}}} * CF$$

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 ⁶⁴²
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%

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.

⁶⁴¹ 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.

⁶⁴² This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

Building Type	CF ⁶⁴²
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ⁶⁴³	79.8%

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta\text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}}\right) * \text{Area} * \text{CRF} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

- R_{existing} = Roof heat loss coefficient with existing insulation (or IECC 2012 code baseline for NC) [(hr-°F-ft²)/Btu]
- R_{new} = Roof heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- Area = Area of the roof surface in square feet. Assume 1000 sq ft for planning.
- EFLH_{heating} = Equivalent Full Load Hours for Heating 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
= Actual

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 ⁶⁴⁴
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296

⁶⁴³ For weighting factors, see HVAC variable table in section 3.3.

⁶⁴⁴ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

Building Type	GCF ⁶⁴⁴
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ⁶⁴⁵	0.012386

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-RINS-V01-170101

SUNSET DATE: 1/1/2020

⁶⁴⁵ 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

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * CRF * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

- $R_{existing}$ = Wall assembly heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
- R_{new} = Wall assembly heat loss coefficient with new insulation [(hr-°F-ft²)/Btu]
- Area = Area of the wall surface in square feet.
- CRF = Correction Factor. Adjustment to account for the effects the framing has on the overall assembly R-value, when cavity insulation is used.
 - = 100% if Spray Foam or External Rigid Foam
 - = 50% if studs and cavity insulation⁶⁴⁶
- $EFLH_{cooling}$ = 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 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁶⁴⁷	$\Delta T_{AVG,cooling}$ [°F]
Burlington	80.4	5.4

⁶⁴⁶ Consistent with the information listed in ASHRAE, 2001, Table 5-1 Wall Sections with Steel Studs Parallel Path Correction Factors and experimental findings by the Oak Ridge National Laboratory, "Couple Secrets about How Framing is Effecting the Thermal Performance of Wood and Steel-Framed Walls."

⁶⁴⁷ 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

Climate Zone (City based upon)	OA _{AVG,cooling} [°F] ⁶⁴⁷	ΔT _{AVG,cooling} [°F]
Des Moines	78.6	3.6
Mason City	75.2	0.2

- 1,000 = Conversion from Btu to kBtu
- η_{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:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(3,412 * \eta_{heating})}$$

Where:

- EFLH_{heating} = Equivalent Full Load Hours for Heating [hr] are provided in Section 4.4, HVAC end use
- ΔT_{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] ⁶⁴⁸	ΔT _{AVG,heating} [°F]
Burlington	39.6	15.4
Des Moines	35.9	19.1
Mason City	30.1	24.9

- 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%*

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:

- ΔTherms = Gas savings calculated with equation below.
- F_e = Percentage of heating energy consumed by fans, assume 3.14%⁶⁴⁹

8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

⁶⁴⁸ 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.

⁶⁴⁹ 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

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 ⁶⁵⁰
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ⁶⁵¹	79.8%

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(100,000 * \eta_{heat})}$$

Where:

R_{existing} = Wall heat loss coefficient with existing insulation [(hr-°F-ft²)/Btu]
 R_{new} = 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.
 EFLH_{heating} = Equivalent Full Load Hours for Heating 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

⁶⁵⁰ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁶⁵¹ For weighting factors, see HVAC variable table in section 3.3.

= 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 ⁶⁵²
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ⁶⁵³	0.012386

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-WINS-V01-170101

SUNSET DATE: 1/1/2020

⁶⁵² Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

⁶⁵³ 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.⁶⁵⁴

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be \$1.50 per square foot of window area.⁶⁵⁵

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

⁶⁵⁴ Consistent with window measure lives specified in the MidAmerican Energy Company Joint Assessment, February 2013.

⁶⁵⁵ Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007. Consistent with other market reports.

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

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{(U_{code} - U_{eff}) * A_{window} * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

U_{code} = U-factor value of code baseline window assembly (Btu/ft².°F.h)
 = Dependent on climate zone and window type. 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)

$EFLH_{cooling}$ = 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 75°F indoor air temperature

Climate Zone (City based upon)	$O_{AVG,cooling}$ [°F] ⁶⁵⁶	$\Delta T_{AVG,cooling}$ [°F]
Burlington	80.4	5.4
Des Moines	78.6	3.6
Mason City	75.2	0.2

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
 = 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:

⁶⁵⁶ 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.

$$\Delta kWh_{\text{heating}} = \frac{(U_{\text{code}} - U_{\text{eff}}) * A_{\text{window}} * EFLH_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(3,412 * \eta_{\text{heating}})}$$

Where:

$EFLH_{\text{heating}}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 4.4, HVAC 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] ⁶⁵⁷	$\Delta T_{\text{AVG,heating}}$ [°F]
Burlington	39.6	15.4
Des Moines	35.9	19.1
Mason City	30.1	24.9

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

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%⁶⁵⁸

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{\Delta kWh_{\text{cooling}}}{EFLH_{\text{cooling}}} * CF$$

Where:

$EFLH_{\text{cooling}}$ = Equivalent full load hours of air conditioning are provided in Section 3.3, HVAC end use

⁶⁵⁷ 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.

⁶⁵⁸ 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.

CF = Summer System Peak Coincidence Factor for Cooling (dependent on building type)

Building Type	CF ⁶⁵⁹
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ⁶⁶⁰	79.8%

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta\text{Therms} = \frac{(U_{code} - U_{eff}) * A_{window} * EFLH_{heating} * \Delta T_{AVG,heating}}{(100,000 * \eta_{heat})}$$

Where:

U_{code} = U-factor value of code baseline window assembly (Btu/ft².°F.h)
 = 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)

EFLH_{heating} = Equivalent Full Load Hours for Heating 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

⁶⁵⁹ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand, from eQuest models.

⁶⁶⁰ For weighting factors, see HVAC variable table in section 3.3.

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

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 ⁶⁶¹
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ⁶⁶²	0.012386

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-WIND-V01-170101

SUNSET DATE: 1/1/2020

⁶⁶¹ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

⁶⁶² For weighting factors, see HVAC variable table in section 3.3.

3.7.6 Insulated Doors

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is insulation levels that exceed code requirements and should be determined by the program.

DEFINITION OF BASELINE EQUIPMENT

The retrofit baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire door assembly. 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.⁶⁶³

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)
- 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

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}} \right) * Area * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1,000 * \eta_{cooling})}$$

Where:

⁶⁶³ 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 2.7 for swinging door, 4.75 for nonswinging door⁶⁶⁴.
- R_{new} = New door heat loss coefficient [(hr-°F-ft²)/Btu]
- Area = Area of the door surface in square feet.
- $EFLH_{cooling}$ = 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 75°F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F] ⁶⁶⁵	$\Delta T_{AVG,cooling}$ [°F]
Burlington	80.4	5.4
Des Moines	78.6	3.6
Mason City	75.2	0.2

- 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 55°F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F] ⁶⁶⁶	$\Delta T_{AVG,heating}$ [°F]
Burlington	39.6	15.4
Des Moines	35.9	19.1
Mason City	30.1	24.9

- 3,142 = Conversion from Btu to kWh.
- $\eta_{heating}$ = Efficiency of heating system

⁶⁶⁴ IECC 2012 and 2015 code requirement

⁶⁶⁵ 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.

⁶⁶⁶ 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%⁶⁶⁷
- 29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (\Delta kWh_{\text{cooling}} / EFLH_{\text{cooling}}) * CF$$

Where:

- $EFLH_{\text{cooling}}$ = 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 ⁶⁶⁸
Convenience	92.3%
Education	61.9%
Grocery	90.6%
Health	88.2%
Hospital	95.0%
Industrial	44.6%
Lodging	88.8%
Multifamily	88.8%
Office - Large	74.2%
Office - Small	70.9%
Religious	94.3%
Restaurant	91.5%
Retail - Large	87.6%
Retail - Small	87.7%
Warehouse	77.9%
Nonresidential Average ⁶⁶⁹	79.8%

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

⁶⁶⁷ 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.

⁶⁶⁸ This calculation is the total savings in peak hour demand divided by the total savings in absolute peak demand.

⁶⁶⁹ For weighting factors, see HVAC variable table in section 3.3.

$$\Delta\text{Therms} = \frac{\left(\frac{1}{R_{\text{existing}}} - \frac{1}{R_{\text{new}}}\right) * \text{Area} * \text{EFLH}_{\text{heating}} * \Delta T_{\text{AVG,heating}}}{(100,000 * \eta_{\text{heat}})}$$

Where:

- R_{existing} = 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.
- $\text{EFLH}_{\text{heating}}$ = Equivalent Full Load Hours for Heating are provided in Section 3.3, HVAC 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

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 ⁶⁷⁰
Convenience	0.016482
Education	0.014346
Grocery	0.022412
Health	0.013368
Hospital	0.021184
Industrial	0.014296
Lodging	0.011829
Multifamily	0.011829
Office - Large	0.010352
Office - Small	0.011789
Religious	0.011964
Restaurant	0.013452
Retail - Large	0.014291
Retail - Small	0.012009
Warehouse	0.012093
Nonresidential Average ⁶⁷¹	0.012386

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

⁶⁷⁰ Calculated as the percentage of total savings in the maximum saving day, from eQuest models.

⁶⁷¹ For weighting factors, see HVAC variable table in section 3.3.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-SHL-DOOR-V01-170101

SUNSET DATE: 1/1/2020

3.8 Refrigeration

3.8.1 LED Refrigerator Case Light Occupancy Sensor

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. 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.⁶⁷²

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.⁶⁷³

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 344.8 kWh per control for coolers and 392.9 kWh per control for freezers..

⁶⁷²2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

⁶⁷³ Measure cost from Efficiency Vermont No. 2015-90 TRM. Based on information provided by Green Mountain Electric Supply for a Wattstopper FS705 product.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.8.1 LED Refrigerator Case Light Occupancy Sensor

$$\Delta kWh = ((kW_{Controlled} * (1 - \%Save)) * (Hours * \%Controlled) * (1 + (0.80/COP)))$$

Where:

- kW_{Controlled} = Total lighting load (kW) connected to the control.
= Actual, or if unknown, assume 0.184 kW⁶⁷⁴
- %Save = Percentage of full load wattage due to occupancy sensor
= Actual or if unknown, assume 20%⁶⁷⁵
- Hours = Annual case lighting hours of use
= Actual or if unknown, assume 6,575 hours⁶⁷⁶
- %Controlled = Percentage of time case lighting operates at reduced wattage due to the occupancy sensor
= Actual or if unknown, assume 29%⁶⁷⁷
- 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 and 2.0 for freezers⁶⁷⁸

EXAMPLE

For example, a cooler with an LED case light occupancy sensor installed, using the defaults above, would save:

$$\begin{aligned} \Delta kWh &= ((kW_{Controlled} * (1 - \%Save)) * (Hours * \%Controlled) * (1 + (0.80 / COP))) \\ \Delta kWh &= ((0.184 * (1 - 0.20)) * (6,575 * 0.29) * (1 + (0.80 / 3.5))) \\ &= 344.8 kWh per control \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh = Electric energy savings, calculated above
- CF = Summer peak coincidence factor

⁶⁷⁴ Controlled lighting load from Efficiency Vermont No. 2015-90 TRM, based on LED Refrig Lighting ERCO_Talking_PointsV3, PG&E

⁶⁷⁵ Regional Technical Forum (RTF) Unit Energy Savings (UES) Measures and Supporting Documentation: Grocery – Display Case Motion Sensors v.3.1

⁶⁷⁶ Assumption for a business operating 18 hours per day

⁶⁷⁷ Regional Technical Forum (RTF) Unit Energy Savings (UES) Measures and Supporting Documentation: Grocery – Display Case Motion Sensors v.3.1

⁶⁷⁸ 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.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.8.1 LED Refrigerator Case Light Occupancy Sensor

= 1.00 for all building types

Other variables as defined above

EXAMPLE

For example, a cooler with an LED case light occupancy sensor installed, using the defaults above, would save:

$$\begin{aligned}\Delta kW &= (344.8 / 6,575) * 1.00 \\ &= 0.0524 \text{ kW}\end{aligned}$$

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-CLOS-V01-170101

SUNSET DATE: 1/1/2019

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.⁶⁷⁹

DEEMED MEASURE COST

The incremental capital cost \$1,266 per heater control.⁶⁸⁰

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use 963.0 kWh per door for coolers and 1,663.8 kWh per door for freezers.⁶⁸¹

⁶⁷⁹ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

⁶⁸⁰ Measure cost from “Incremental Cost Study, Phase Four Final Report.” Northeast Energy Efficiency Partnerships. June 15, 2015.

⁶⁸¹ Algorithm and assumptions from Pennsylvania June 2016 TRM with reference to Wisconsin 2010 Business Programs Deemed Savings Manual v1.0

$$\Delta kWh = DoorFt \times \left(\frac{kW_{Base}}{DoorFt} \times Hours \times \%Off \times \left(1 + \frac{R_H}{COP} \right) \right)$$

Where:

- kWBase = Per door electric energy consumption of door heater without controls
= Assume 0.109 kW for coolers and 0.191 kW for freezers⁶⁸²
- DoorFt = Door length in liner feet
= Actual or if unknown, use 2.5 feet⁶⁸³
- Hours = Annual hours of cooler or freezer operation
= Assume 8,766 hours per year
- %Off = Percentage of hours annually that the door heater is powered off due to controls
= Actual or if unknown, assume 85% for coolers and 75% for freezers⁶⁸⁴
- 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 0.65⁶⁸⁵
- COP = Coefficient of performance of cooler or freezer
= Actual or if unknown, use 3.5 for coolers and 2.0 for freezers⁶⁸⁶

EXAMPLE

For example, a cooler with a door heater control would save:

$$\begin{aligned} \Delta kWh &= DoorFt * (kW_{Base}/DoorFt * Hours * \%Off * (1+R_H/COP)) \\ \Delta kWh &= 2.5 * (0.109/2.5 * 8,766 * 0.85 * (1+0.65/3.5)) \\ &= 963.0 kWh per door \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

⁶⁸² Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁶⁸³ Review of various manufacturers’ web sites yields 2.5’ average door length. Sites include: http://www.bushrefrigeration.com/bakery_glass_door_coolers.php, <http://www.brcc.com/home.php?cat=427>, and http://refrigeration-equipment.com/gdm_s_c_series_swing_door_reac.html

⁶⁸⁴ Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁶⁸⁵ Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁶⁸⁶ 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.

Δ kWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor
= 0.964

Other variables as defined above.

EXAMPLE

For example, a cooler with a door heater control would save:

$$\begin{aligned}\Delta kW &= (963.0/8766) * 0.964 \\ &= 0.1059 \text{ kW per door}\end{aligned}$$

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-V01-170101

SUNSET DATE: 1/1/2019

3.8.3 Electronically Commutated Motors (ECM) 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) 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 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.⁶⁸⁷

DEEMED MEASURE COST

Retrofit cost for a brushless DC fan motor is \$245 (\$185 for the motor, \$60 for installation labor including travel time).⁶⁸⁸

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below,⁶⁸⁹ otherwise use 292.9 kWh for coolers and 321.3 kWh for freezers:

$$\Delta kWh = \frac{W_{Output} / EFF_{Base} - W_{Output} / EFF_{ECM}}{1,000} \times Hours \times DC \times LF \times \left(1 + \frac{1}{COP}\right)$$

Where:

W_{Output} = Output wattage of installed fan motor

⁶⁸⁷ DEER 2014

⁶⁸⁸ Motor cost is an average of costs from Natural Resource Management (\$250) and direct from the manufacturer GE (\$120)

⁶⁸⁹ Algorithm and assumptions from Pennsylvania June 2016 TRM and Efficiency Vermont October 22, 2015 TRM

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.8.3 Electronically Commutated Motors (ECM) for Walk-in and Display Case Coolers / Freezers

	= Actual or if unknown, use 14.95 W ⁶⁹⁰
EFF _{Base}	= Efficiency of baseline motor
	= Actual or if unknown, use 29% ⁶⁹¹
EFF _{ECM}	= Efficiency of ECM motor
	= Actual or if unknown, use 66% ⁶⁹²
1,000	= Conversion factor from watts to kilowatts
Hours	= Annual hours of cooler or freezer operation
	= Assume 8,766 hours
LF	= Load factor of fan motor
	= Actual or if unknown, assume 0.90 ⁶⁹³
DC	= Duty cycle of fan motor
	= Custom or if unknown, assume 100% for coolers and 94% for freezers ⁶⁹⁴
COP	= Coefficient of performance of cooler or freezer
	= Actual or if unknown, use 3.5 for coolers and 2.0 for freezers ⁶⁹⁵

EXAMPLE

For example, a cooler with an ECM motor installed in place of a PSC motor, using the defaults above, would save:

$$\Delta kWh = (W_{Output} / EFF_{Base} - W_{Output} / EFF_{ECM}) / 1,000 \times Hours \times DC \times LF \times (1 + 1/COP)$$

$$\Delta kWh = (14.95/0.29 - 14.95/0.66) / 1,000 * 8766 * 1.00 * 0.90 * (1 + 1/3.5)$$

$$= 292.9 kWh$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above

⁶⁹⁰ 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

⁶⁹¹ Chapter 5 of Technical Support Document in support of DOE Notice of Proposed Rulemaking for Commercial Refrigeration Equipment, 08/28/2013

⁶⁹² Chapter 5 of Technical Support Document in support of DOE Notice of Proposed Rulemaking for Commercial Refrigeration Equipment, 08/28/2013

⁶⁹³ Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010

⁶⁹⁴ Duty cycle from Efficiency Vermont October 22, 2015 TRM: "An evaporator fan in a cooler runs all the time, but a freezer only runs 8,273 hours per year due to defrost cycles (4 20-min defrost cycles per day)."

⁶⁹⁵ 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.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.8.3 Electronically Commutated Motors (ECM) for Walk-in and Display Case Coolers / Freezers

CF = Summer peak coincidence factor
= 0.964

Other variables as defined above.

EXAMPLE

For example, a cooler with an ECM motor installed in place of a PSC motor, using the defaults above, would save:

$$\begin{aligned}\Delta kW &= (292.9/8766) * 0.964 \\ &= 0.0322 \text{ kW}\end{aligned}$$

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-V01-170101

SUNSET DATE: 1/1/2019

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 2014.⁶⁹⁶

DEEMED MEASURE COST

The incremental capital cost for this measure is \$42 per linear foot of cover installed including material and labor.⁶⁹⁷

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

⁶⁹⁶ 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

⁶⁹⁷ 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 below⁶⁹⁸, depending on display case temperature

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 day⁶⁹⁹

Days = Number of days per year that night covers are in use
 = Actual or if unknown, use 365.25 days per year

EXAMPLE

For example, a low-temperature display case with night covers installed on a 12-foot wide opening, using the defaults above, would save:

$$\Delta kWh = \text{CaseFt} * \text{SavingsRate} * \text{Hours} * \text{Days}$$

$$\Delta kWh = 12 * 0.03 * 6 * 365.25$$

$$= 788.9 \text{ kWh}$$

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-V01-170101

⁶⁹⁸ "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.

⁶⁹⁹ 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.

SUNSET DATE: 1/1/2019

3.8.5 Refrigerated Beverage Vending Machine

DESCRIPTION

This measure applies to new ENERGY STAR, Class A or Class B refrigerated vending machines. 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 or Class B⁷⁰⁰ refrigerated vending machine meeting energy consumption requirements as determined by equipment type (Class A or Class B).

ENERGY STAR Requirements (Version 3.1, Effective March 1, 2013)

Equipment Type	Maximum Daily Energy Consumption (kWh/day)
Class A	$\leq 0.0523V + 2.432$
Class B	$\leq 0.0657V + 2.844$

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new or rebuilt, Class A or Class B refrigerated vending machine that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.⁷⁰¹

DEEMED MEASURE COST

The incremental cost of this measure is \$0.⁷⁰²

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

⁷⁰⁰ Class A means a refrigerated bottled or canned beverage vending machine that is fully cooled, and is not a combination vending machine. Class B means any refrigerated bottled or canned beverage vending machine not considered to be Class A, and is not a combination vending machine. See 10 CFR §431.292 “Definitions concerning refrigerated bottled or canned beverage vending machines”

⁷⁰¹ Measure life from Final Report: Volume 2, Assessment of Energy and Capacity Savings Potential in Iowa: Appendices. The Cadmus Group, February 28, 2012

⁷⁰² Incremental cost from Final Report: Volume 2, Assessment of Energy and Capacity Savings Potential in Iowa: Appendices

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}^{703}
Class A	$0.055V + 2.56$
Class B	$0.073V + 3.16$

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}^{704}
Class A	$\leq 0.0523V + 2.432$
Class B	$\leq 0.0657V + 2.844$

V = Refrigerated volume⁷⁰⁵ (ft³)
 = Actual installed

Days = Days of vending machine operation per year
 = 365.25 days per year

EXAMPLE

For example, an ENERGY STAR, Class A vending machine with a volume of 30 ft³ would save:

$$\begin{aligned} \Delta kWh &= (kWh_{Base} - kWh_{ESTAR}) * Days \\ \Delta kWh &= [(0.055 * 30 + 2.56) - (0.0523 * 30 + 2.432)] * 365.25 \\ &= 76.3 kWh \end{aligned}$$

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

ΔkWh = Electric energy savings, calculated above
 Hours = Hours of vending machine operation per year

⁷⁰³10 CFR §431.296 - Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines

⁷⁰⁴ ENERGY STAR Version 3.1 requirements for maximum daily energy consumption

⁷⁰⁵V is measured by the American National Standards Institute (ANSI)/Association of Home Appliance Manufacturers (AHAM) HRF-1-2004, "Energy, Performance and Capacity of Household Refrigerators, Refrigerator-Freezers and Freezers." Measurement of refrigerated volume must be in accordance with the methodology specified in Section 5.2, Total Refrigerated Volume (excluding subsections 5.2.2.2 through 5.2.2.4), of ANSI/AHAM HRF-1-2004

$$= 8,766^{706}$$

CF = Summer peak coincidence factor

$$= 0.964$$

EXAMPLE

For example, an ENERGY STAR vending machine with a volume of 30 ft³ would save:

$$\begin{aligned}\Delta kW &= (76.3/8,766) * 0.964 \\ &= 0.0084 \text{ kW}\end{aligned}$$

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-V01-170101

SUNSET DATE: 1/1/2019

⁷⁰⁶ Equipment is assumed to operate continuously, 24 hour per day, 365.25 days per year

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 2011 Cadmus analysis of data from a number of evaluations⁷⁰⁷. 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

N/A

DEFINITION OF BASELINE EQUIPMENT

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

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated remaining useful life of the recycling units is 8 years⁷⁰⁸.

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 \$120⁷⁰⁹ per unit.

LOADSHAPE

Loadshape RE09 - Residential Refrigerator

Loadshape RE02 – Residential Freezer

Algorithm

CALCULATION OF SAVINGS

⁷⁰⁷ Cadmus, 2011; “2010 Residential Great Refrigerator Roundup Program – Impact Evaluation”

⁷⁰⁸ KEMA “Residential refrigerator recycling ninth year retention study”, 2004

⁷⁰⁹ Based on similar Efficiency Vermont program.

ENERGY SAVINGS

Regression analysis; Refrigerators

Energy savings for refrigerators are based upon a linear regression model using the following coefficients⁷¹⁰:

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 location⁷¹¹:

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

- Unconditioned = If unit in unconditioned space = 1, otherwise 0
- HDD = Heating Degree Days

⁷¹⁰ 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.

⁷¹¹ National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

= Dependent on location:⁷¹²

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

$UEC_{BaseRefrig}$ = Assumed consumption of a new baseline residential-sized refrigerator
 = 592 kWh⁷¹³

Deemed approach; Refrigerators

$$\Delta kWh_{Unit} = UEC_{Retired} - UEC_{BaseRefrig}$$

Where:

$UEC_{Retired}$ = Unit Energy Consumption of retired unit
 = 1106 kWh⁷¹⁴

$$\Delta kWh_{Unit} = 1106 - 592$$

$$= 514 \text{ kWh}$$

Regression analysis; Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients⁷¹⁵:

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:

⁷¹² National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.

⁷¹³ 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.

⁷¹⁴ This value is taken from the 2011 Cadmus evaluation analysis with 4 years of degradation (3.7%) as a reasonable estimate for 2015 and beyond.

⁷¹⁵ 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.

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 kWh ⁷¹⁶

Deemed approach; Freezers

$$\Delta kWh_{Unit} = UEC_{Retired} - UEC_{BaseFreezer}$$

Where:

UEC _{Retired}	= Unit Energy Consumption of retired unit = 919 kWh ⁷¹⁷
ΔkWh_{Unit}	= 919 - 381 = 538 kWh

Additional Waste Heat Impacts⁷¹⁸

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

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

Where:

ΔkWh_{Unit}	= kWh savings calculated from either method above
WHFeHeatElectric	= Waste Heat Factor for Energy to account for electric heating increase from removing waste heat from refrigerator/freezer (if fossil fuel heating – see calculation of heating penalty in that section). = - (HF / $\eta_{HeatElectric}$) * %ElecHeat
HF	= Heating Factor or percentage of reduced waste heat that must now be heated = 54% for unit in heated space ⁷¹⁹ = 0% for unit in unheated space
$\eta_{HeatElectric}$	= Efficiency in COP of Heating equipment = Actual - If not available, use ⁷²⁰ :

⁷¹⁶ 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.

⁷¹⁷ This value is taken from the 2011 Cadmus evaluation analysis with 4 years of degradation (3.7%) as a reasonable estimate for 2015 and beyond.

⁷¹⁸ 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.

⁷¹⁹ Based on 197 days where HDD 55>0, divided by 365.25.

⁷²⁰ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 and 2015 the Federal

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (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	1.38 ⁷²¹

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

Heating fuel	$\%ElecHeat$
Electric	100%
Fossil Fuel	0%
Unknown	30% ⁷²²

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

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

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

= 34% for unit in cooled space⁷²³

= 0% for unit in uncooled space

η_{Cool} = Efficiency in COP of Cooling equipment

= Actual - If not available, assume 2.8 COP⁷²⁴

$\%Cool$ = Percentage of businesses with cooling

AC use	$\%Cool$
Cooling	100%
No Cooling	0%
Unknown	74% ⁷²⁵

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.

⁷²¹ 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.

⁷²² 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).

⁷²³ Based on 123 days where CDD 65>0, divided by 365.25.

⁷²⁴ Starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm $(-0.02 * SEER^2) + (1.12 * SEER)$ (from Wassmer, M. (2003); A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

⁷²⁵ 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).

SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- ΔkWh_{Unit} = Savings provided in algorithm above (not including $\Delta kWh_{wasteheat}$)
- HOURS = Equivalent Full Load Hours as calculated using eShapes loadprofile
 - Refrigerators = 5280
 - Freezers = 5895
- WHFdCool = Waste heat factor for demand to account for cooling savings from removing waste heat⁷²⁶.

Refrigerator Location	WHFdCool
Cooled space	1.29 ⁷²⁷
Uncooled or unknown space	1.0
Unknown space	1.21

- CF = Coincident factor as calculated using eShapes loadprofile
 - Refrigerators = 70.9%
 - Freezers = 95.3%

Deemed approach; Refrigerators

$$\begin{aligned} \Delta kW &= 514/5280 * 1.21 * 0.709 \\ &= 0.0835 kW \end{aligned}$$

Deemed approach; Freezers

$$\begin{aligned} \Delta kW &= 538/5895 * 1.21 * 0.953 \\ &= 0.1052 kW \end{aligned}$$

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).⁷²⁸

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

Where:

- ΔkWh_{Unit} = kWh savings calculated from either method above, not including the $\Delta kWh_{WasteHeat}$
- WHFeHeatGas = Waste Heat Factor for Energy to account for gas heating increase from removing waste heat from refrigerator/freezer
 - = - (HF / $\eta_{HeatGas}$) * %GasHeat

⁷²⁶ 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.

⁷²⁷ 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.

⁷²⁸ 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.

If unknown, assume 0

HF = Heating Factor or percentage of reduced waste heat that must now be heated
 = 54% for unit in heated space⁷²⁹
 = 0% for unit in heated space

η_{HeatGas} = Efficiency of heating system
 = 74%⁷³⁰

%GasHeat = Percentage of businesses with gas heat

Heating fuel	%GasHeat
Electric	0%
Gas	100%
Unknown	70% ⁷³¹

0.03412 = Converts kWh to Therms

PEAK GAS SAVINGS

Heating penalty for reduction in waste heat, only for retired units from conditioned space in gas heated 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
 = 197⁷³²

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

⁷²⁹ Based on 197 days where HDD 55>0, divided by 365.25.

⁷³⁰ 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: $((0.60 \cdot 0.92) + (0.40 \cdot 0.8)) \cdot (1 - 0.15) = 0.74$. Heating assumptions for small commercial buildings are expected to be similar to assumptions for residential buildings.

⁷³¹ 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).

⁷³² Number of days where HDD 55 >0.

N/A

MEASURE CODE: NR-REF-RFRC-V01-170101

SUNSET DATE: 1/1/2019

3.8.7 Scroll Refrigeration Compressor

DESCRIPTION

This measure applies to scroll refrigerant compressors utilized in commercial refrigeration including supermarkets, foodservices and convenience store applications⁷³³. Super market 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 continuously⁷³⁴. 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 1.0-10 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

In order for this characterization to apply, the efficient system is assumed to be a scroll refrigeration compressor replacing a reciprocating compressor.⁷³⁵

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 years⁷³⁶.

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

⁷³³ 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.

⁷³⁴ 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.

⁷³⁵ Following the expansion of highly efficient motors rules effective March 2015, the US DOE is also proposing to regulate the efficiency level of pumps, fans and compressors to improve overall system efficiency. According to the current rulemaking status (Nov 2014) the final ruling for compressors will be in July 2016 with compliance expected in July 2021. Suggest review of measure recommendations following new rulings.

⁷³⁶ 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 SAVINGS KWH

$$\Delta kWh = \frac{\left((Avg\ Cap * FLH) * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}} \right) \right)}{1000} * units$$

Where:

- Avg Cap = compressor capacity in Btu/h. See reference table for values. For prescriptive measures the average capacity for each range of size is used⁷³⁷.
- 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 3910 hours for medium temperature applications and 4139 hours for low temperature applications.⁷³⁸
- 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 3910 hours for medium temperature applications and 4139 hours for low temperature applications.⁷³⁹
- CF = System Peak Coincidence Factor. Assume non-residential average of 96.4%

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

⁷³⁷ 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.

⁷³⁸ 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

⁷³⁹ 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

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

REFERENCE TABLES⁷⁴⁰

Baseline and Qualifying EER Values by Capacity, and Temperature Application⁷⁴¹

Low Temperature			
Baseline and Qualifying EER			
Condensing temp 90°F, Evap Temp -25°F			
Capacity Bins in BTU/Hr	HP equivalent ⁷⁴²	Average EERbase	Average EERee
0-4200	1	3.85	4.39
4200-8399	2	4.83	5.21
8400-12599	3	5.06	5.37
12600-16799	4	5.26	5.59
16800-20999	5	5.36	5.80
21000-25199	6	5.69	6.06
25200-29399	7	5.71	6.15
29400-33599	8	6.14	6.39
33600-37800	9	5.64	6.06
37800-42000	10	5.73	6.06
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

⁷⁴⁰ 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.

⁷⁴¹ 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 15°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.

⁷⁴² 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.

MEASURE CODE: MEASURE CODE: NR-RFG-SCR-V01-170101

SUNSET DATE: 1/1/2019

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.⁷⁴³

DEEMED MEASURE COST

The incremental capital cost for this measure is \$10.22 per square foot, including materials and labor.⁷⁴⁴

LOADSHAPE

Loadshape NRE01 - Nonresidential Refrigeration – Grocery

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below⁷⁴⁵, 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

⁷⁴³ DEER 2014 Effective Useful Life

⁷⁴⁴ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”, California Public Utilities Commission, December 16, 2008.

⁷⁴⁵ Algorithms and assumptions from Regional Technical Forum (RTF) Unit Energy Savings (UES) Measures and Supporting Documentation: Grocery – Strip Curtains v.1.4

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.8.8 Strip Curtain for Walk-in Coolers and Freezers

= 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

EXAMPLE

For example, a cooler with strip curtains installed at a grocery store, using the defaults from above, would save:

$$\Delta kWh = ((Q_{Base}/EER \times 1000) - (Q_{EE}/EER \times 1000)) \times EFLH/A \times A$$

$$\begin{aligned} \Delta kWh &= ((4,661/10.6 \times 1000) - (559/10.6 \times 1000)) \times 7,693/21 \times 21 \\ &= 2,988.1 \text{ kWh} \end{aligned}$$

Savings for grocery stores, restaurants, convenient stores, and unknown building types⁷⁴⁶ are presented in the table below.

	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

$$\Delta kW = (\Delta kWh/EFLH) * CF$$

⁷⁴⁶ Savings for unknown building types represent the average of grocery store, restaurant, and convenience store savings.

Iowa Energy Efficiency Statewide Technical Reference Manual – 3.8.8 Strip Curtain for Walk-in Coolers and Freezers

Where:

Δ kWh = Electric energy savings, calculated above

CF = Summer peak coincidence factor

= 0.964

Other variables as defined above.

EXAMPLE

For example, a cooler with strip curtains installed at a restaurant, using the defaults above, would save:

$$\Delta kW = (2,988.1/7,693) * 0.964$$

$$= 0.3744 \text{ kW}$$

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-STCR-V01-170101

SUNSET DATE: 1/1/2019

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.

ENERGY STAR Requirements (Version 2.0, Effective February 1, 2013)

ENERGY STAR Requirements for Air-Cooled Batch-Type Ice Makers			
Equipment Type	Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	Energy Consumption Rate (kWh/100 lbs ice)	Potable Water Use (gal/100 lbs ice)
IMH	$200 \leq H \leq 1600$	$\leq 37.72 * H^{-0.298}$	≤ 20.0
RCU	$400 \leq H \leq 1600$	$\leq 22.95 * H^{-0.258} + 1.00$	≤ 20.0
	$1600 \leq H \leq 4000$	$\leq -0.00011 * H + 4.60$	≤ 20.0
SCU	$50 \leq H \leq 450$	$\leq 48.66 * H^{-0.326} + 0.08$	≤ 25.0
ENERGY STAR Requirements for Air-Cooled Continuous-Type Ice Makers			
Equipment Type	Energy Consumption Rate (kWh/100 lbs ice)		Potable Water Use (gal/100 lbs ice)
IMH	$\leq 9.18 * H^{-0.057}$		≤ 15.0
RCU	$\leq 6.00 * H^{-0.162} + 3.50$		≤ 15.0
SCU	$\leq 59.45 * H^{-0.349} + 0.08$		≤ 15.0

DEFINITION OF BASELINE EQUIPMENT

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 8 years.⁷⁴⁷

DEEMED MEASURE COST

The incremental capital cost for this measure is \$0.⁷⁴⁸

LOADSHAPE

Loadshape NRE01 - Nonresidential Electric Refrigeration – Restaurant

⁷⁴⁷Measure life from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

⁷⁴⁸Incremental costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator. Calculator cites EPA research using AutoQuotes, 2012.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed values from the table that follows.⁷⁴⁹

$$\Delta kWh = \left[\frac{(kWh_{Base} - kWh_{ESTAR})}{100} \right] * (Duty * H) * Days$$

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)

Energy Consumption of Air-Cooled Batch-Type Ice Makers				
Ice Maker Type	kWh _{Base}		kWh _{ESTAR}	
IMH	H < 450	10.26 - 0.0086*H	200 ≤ H ≤ 1600	37.72 * H ^{-0.298}
	H ≥ 450	6.89 - 0.0011*H		
RCU	H < 1000	8.85 - 0.0038*H	400 ≤ H ≤ 1600	22.95 * H ^{-0.258} + 1.00
	H ≥ 1000	5.1	1600 ≤ H ≤ 4000	0.00011 * H + 4.60
SCU	H < 175	18 - 0.0469*H	50 ≤ H ≤ 450	48.66 * H ^{-0.326} + 0.08
	H ≥ 175	9.8		

Energy Consumption of Air-Cooled Continuous-Type Ice Makers		
Ice Maker Type	kWh _{Base}	kWh _{ESTAR}
IMH	9.18 * H ^{-0.057} + 1	9.18 * H ^{-0.057}
RCU	6 * H ^{-0.162} + 4.2	6.00 * H ^{-0.162} + 3.50
SCU	59.45 * H ^{-0.349} + 0.68	59.45 * H ^{-0.349} + 0.08

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

⁷⁴⁹ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

EXAMPLE

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

$$\begin{aligned} \Delta kWh &= [((6.89 - 0.0011 * 650) - (37.72 * 650^{-0.298})) / 100] * (0.75 * 650) * 365.25 \\ &= [((6.175) - (5.47)) / 100] * (0.75 * 650) * 365.25 \\ &= 1,247.8 \text{ kWh} \end{aligned}$$

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	10,995.2	9,747.4	1,247.8
RCU	16,066.4	14,885.0	1,181.5
SCU	4,669.5	4,284.9	384.6
Energy Consumption of Air Cooled Continuous-Type Ice Makers			
Ice Maker Type	kWh _{Base}	kWh _{ESTAR}	Savings (kWh)
IMH	13,653.8	11,791.0	1,862.8
RCU	19,584.0	17,340.4	2,243.5
SCU	6,219.0	5,824.5	394.5

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh / (Hours * Days) * CF$$

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
= 0.964

Other variables as defined above.

EXAMPLE

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

$$\begin{aligned} \Delta kW &= 1,247.8 / (12 * 365.25) * 0.964 \\ &= 0.2744 \text{ kW} \end{aligned}$$

NATURAL GAS ENERGY SAVINGS

N/A

PEAK GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below, otherwise use deemed values from the table that follows.⁷⁵⁰

$$\Delta Water = \left[\frac{(WaterUse_{Base} - WaterUse_{ESTAR})}{100} \right] * (Duty * H) * Days$$

WaterUse_{Base} = Potable water use (gal / 100 pounds of ice) of baseline ice maker
 = Use value from table below as determined by equipment type

WaterUse_{ESTAR} = Potable water use (gal / 100 pounds of ice) of ENERGY STAR ice maker
 = Custom or if unknown, use value from table below as determined by equipment type

Potable Water Use of Air-Cooled Batch-Type Ice Makers		
Ice Maker Type	WaterUse _{Base}	WaterUse _{ESTAR}
IMH	21.8	18.3
RCU	20.1	18.0
SCU	30.1	19.5
Potable Water Use of Air Cooled Continuous-Type Ice Makers		
Ice Maker Type	WaterUse _{Base}	WaterUse _{ESTAR}
IMH	12.0	12.0
RCU	12.0	12.0
SCU	12.0	12.0

100 = Factor to convert WaterUse_{Base} and WaterUse_{ESTAR} into water use per pound of ice
 Other variables as defined above.

EXAMPLE

For example, an air-cooled, batch-type ice maker with an ice-making head producing 650 pounds of ice would save:

$$\begin{aligned} \Delta WaterUse &= [(21.8 - 18.3) / 100] * (0.75 * 650) * 365.25 \\ &= 6,232.1 \text{ gal/year} \end{aligned}$$

Savings for all ice maker types are presented in the table below.

⁷⁵⁰ Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

Potable Water Use of Air-Cooled Batch-Type Ice Makers			
Ice Maker Type	WaterUse _{Base}	WaterUse _{ESTAR}	Savings (gal/year)
IMH	38,816.9	32,584.9	6,232.1
RCU	63,320.7	56,705.1	6,615.6
SCU	14,017.4	9,081.0	4,936.4
Potable Water Use of Air Cooled Continuous-Type Ice Makers			
Ice Maker Type	WaterUse _{Base}	WaterUse _{ESTAR}	Savings (gal/year)
IMH	22,353.3	22,353.3	0.0
RCU	38,460.8	38,460.8	0.0
SCU	7,889.4	7,889.4	0.0

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: NR-RFG-ESIM-V01-170101

SUNSET DATE: 1/1/2019